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Cow Palace Dairy

Quality Assurance Project Plan

Irrigation Water Management

Administrative Order on Consent

SDWA-10-2013-0080

November 20, 2013

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Cow Palace Dairy

Yakima Valley Dairies, Washington

Plan Approvals:

DRAFT DOCUMENT
Kevin M. Freeman, PG
Project Coordinator

DRAFT DOCUMENT
Steve Hicks, PE
Quality Manager

DRAFT DOCUMENT
Scott Stephen, CCA
Site Safety Coordinator/Sampling Team Leader

Quality Assurance Project Plan

Irrigation Water Management

Prepared for:
Cow Palace Dairy, LLC

Prepared by:
ARCADIS U.S., Inc.
695 North Legacy Ridge Drive
Suite 200
Liberty Lake
Washington 99019
Tel 509 928 3369
Fax 509 928 3075

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Acronyms and Abbreviations

AOC	Administrative Order on Consent
ASTM	American Society for Testing and Materials
AFMP	Application Field Management Plan
AWC	available water content
cm^3	cubic centimeter
in^3	cubic inches
CWN	crop water need
DQO	data quality objective
EC	electrical conductivity
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
ft bgs	feet below ground surface
FC	field capacity
g	grams
g/cm^3	grams per cubic centimeter
HSP	Health and Safety Plan
IWMP	Irrigation Water Management Plan
MCL	maximum contaminant level
NMP	Nutrient Management Plan

%AW	percent available water
ppm	parts per million
PARCC	precision, accuracy, representativeness, comparability, and completeness
PC	Project Coordinator
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QC	quality control
SOP	standard operating procedure
SOW	Statement of Work
SU	Sampling Unit
STL	Sampling Team Leader
SSC	Site Safety Coordinator
USCS	Unified Soil Classification System
VWC	volumetric water content
WC	water content
WD	water depletion
WP	wilting point

Distribution List (A3)

Adam Dolson	Cow Palace Dairy
Eric Winiecki	EPA
Gina Greppo-Grove	EPA
Rene Fuentes	EPA
Jennifer MacDonald	EPA
Scott Stephen	Agrimanagment
Kevin Freeman	ARCADIS
Steve Hicks	ARCADIS
Tom Mullen	ARCADIS
Amy Goldberg Day	ARCADIS
Lori Terry Gregory	Foster Pepper

1. Project Management (Group A)

1.1 Project/Task Organization (A4)

This section presents the organization structure and lines of communication that will be followed to implement the irrigation water management activities presented in this Irrigation Water Management Quality Assurance Project Plan (QAPP).

Cow Palace Dairy, LLC (the "Dairy") has retained ARCADIS U.S., Inc. (ARCADIS) and Agrimanagement, Inc. to develop and implement the Irrigation Water Management QAPP. The QAPP has been developed in accordance with requirements identified in Section III.A of the Statement of Work (SOW) (Appendix B of Administrative Order on Consent (AOC) SDWA-10-2013-0080). The QAPP was prepared in accordance with "Guidance for Quality Assurance Project Plans (QA/G-5)" (EPA 2002) and "EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5) (EPA 2001, reissued May 2006). To ensure usability, completeness, and compliance with U.S. Environmental Protection Agency (EPA) guidance, QAPP elements are designated throughout this document by EPA guidance-defined groups, identified by numbers in parentheses next to headings and titles (e.g., A1, A2). In addition to the above guidance, data quality objectives (DQOs) were developed using the requirements included in the SOW and in accordance with the "Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4)" (EPA 2006). DQOs for this Irrigation Water Management QAPP are included in Appendix A.

- The Project Coordinator (PC) will be responsible for the implementation of activities identified in the QAPP and will maintain communication with the EPA PC as required to communicate progress and resolve issues that may arise during the implementation of the QAPP, if necessary. The PC has overall authority over the project team and implementation of the QAPP.

- The Quality Assurance Manager (QAM) will assist in the development and review of project planning documents, evaluation of data, and preparation of deliverables.

- The Site Safety Coordinator/Sampling Team Leader (SSC/STL) will lead the project field team and lead data evaluation and preparation of deliverables.

- The PC and QAM will develop appropriate corrective actions to address any potential quality assurance issues or deficiencies that may occur. Corrective actions will be communicated to the EPA PC and will be implemented and documented by the STL and/or field team, as required.

Laboratory analysis of soil samples will be performed by Agrimanagement, Inc. in the Agrimanagement laboratory located at 408 North 1st Street, Yakima, Washington. Agrimanagement will use standard soil sample analysis methods described in Section 2.2.2 to measure physical parameters needed to determine the soil field capacity and bulk density (wet sample weight and dry sample weight).

1.2 Problem Definition/Background (A5)

1.2.1 Purpose

This Irrigation Water Management QAPP defines and describes that processes and methods that will be employed to perform irrigation water management activities at irrigated cropping fields associated with the Dairy required under Section III.F.2 of the AOC SOW. The QAPP was developed to document the type, quantity, and quality of data needed to meet project objectives and support key decisions, and describes the methods for collecting and assessing data collected as part of QAPP implementation.

1.2.2 Problem Statement

Pursuant to Section III.F.2 of the AOC SOW, the Dairy is required to prepare and submit to the EPA an Irrigation Water Management Plan (IWMP) developed with the assistance of a professional irrigation consultant (Agrimanagement, Inc.) that describes a plan that will be implemented for irrigation water management. Section III.F.2 of the AOC SOW identifies the requirements of the IWMP to include “flow metering to measure the volume of liquid applied to specific fields, and the installation of electronic sensors at the bottom of the root zone in each application field to provide for automatic shut off of the irrigation system to minimize water movement below the root zone.” In order to ensure that the management of irrigation liquids to cropping fields occurs in a manner that minimizes the potential for movement of irrigation water below the root zone, a method to monitor soil moisture conditions and irrigation application volumes and rates is required. The monitoring method must provide sufficient measurement coverage to monitor irrigation liquid volumes and application rates and take into account different crop type moisture needs, soil types, topographic conditions, and irrigation application methods and techniques employed in each irrigated field. Further,

the monitoring method must provide data in sufficient time to allow the professional irrigation consultant and Dairy operator to refine and adjust irrigation liquid application rates and timing to achieve the objective of the plan.

1.2.3 Background

Irrigated agriculture is the principal economic activity in the Yakima River Basin. The relatively mild temperatures within the Yakima River Basin provide a sufficiently long growing season to allow a large number of crops to be grown. However, the relatively low annual precipitation in the Yakima River Basin (approximately 8.22 inches per year at Yakima, Washington) requires that water beyond that received from precipitation be applied to crops in order for crops to grow and achieve the overall agricultural objective of maximizing crop production.

At the Dairy, crop lands are used to produce a portion of the forage and silage needed for animal feed at the Dairy. Water used for irrigation is sourced from the local irrigation districts and nutrients to support crop growth are sourced from liquid manure produced at and stored in lagoons at the Dairy.

1.2.4 Irrigation

Irrigation of crop fields is performed to provide the moisture required for crops to grow and achieve yield goals. The stage of plant growth, crop water needs, crop yield goals, soil properties (water holding capacity and infiltration rates), and topography control the amount of water that is required. If water is applied at rates below those needed to support the crop, crop failure and salt accumulation can result that damage the tilth of the soil. Over-application of irrigation water can result in crop failure by drowning the crop, increased crop production costs, and may also result in the migration of irrigation water below the root zone (Figure 1). In cases where nutrients, specifically nitrogen, are present at concentrations greater than those that can be used by the crop and that can be leached from the soil, over-application of water may result in the leaching of nutrients into the excess water and their movement below the root zone by the excess water. If this occurs, the potential exists for these nutrients to be carried downward through the subsurface to underlying groundwater.

Careful and effective irrigation water management results in crops that receive the appropriate amount of water to achieve crop yield goals, maximizes the use of resources, and minimizes the potential for the movement of excess irrigation water below the root zone. It should be noted that the Dairy can only control field soil

moisture conditions to the extent that reducing or eliminating irrigation liquid application reduces the amount of water entering the soil. Ambient soil moisture conditions or potential saturation events associated with large precipitation or snow melt events are beyond the control of the Dairy and no methods are available that could conceivably be implemented that would allow the Dairy to control soil moisture under these conditions.

Irrigation systems currently in use at the Dairy include the following:

- **Center Pivot** – Method of crop irrigation where a long segmented arm revolves around a central pivot that delivers water through a system of sprinklers located along the arm. The size and application rate of the sprinkler heads along the arm are designed to ensure that the overall application rates across the irrigated area are equal as the segmented arm pivots (smaller sprinklers with lower application rates near the center and larger sprinklers with higher application rates toward the outer radius).

- **Linear** – Method of crop irrigation where a long segmented arm (same construction as the center pivot) moves in a lateral or linear fashion across a field. The system delivers water through a system of sprinklers located along the arm. Sprinkler sizes and application rates are the same across the length of the arm to ensure equal application rates as the liner system moves across the field.

- **Wheel Line** – Method of crop irrigation where long individual pipes, with large wheels and sprinklers attached, are connected to form a long “wheel-line” that is moved across a field. This is a smaller version of the linear irrigation system described above.

- **Reel Gun** – Method of crop irrigation where a travelling gun (large sprinkler) attached to a wheeled cart is placed in one location in the field and then gradually pulled back into a large hose reel at a constant rate. The reel is placed in designated areas to be pulled across field sections. This method of irrigation is typically used in areas where more permanent irrigation systems cannot be installed due to field topography or other conditions that preclude other types of irrigation systems.

Salt accumulation is a relatively common occurrence in irrigated agricultural fields in arid climates. Evaporation, evapotranspiration, and fertilizer application can all lead to the accumulation of salts that can eventually have significant negative impacts on plant growth and crop yield. In order to remove salts from the root zone, salt flushing is

performed where irrigation water is applied in significantly high quantities to dissolve the accumulated salts and move them downward in the soil column. In most agricultural situations, large-scale salt flushing is not required and normal managed irrigation water application and winter precipitation events provide sufficient light flushing to meet cropping requirements. The following factors are taken into consideration when assessing an agricultural field for salt content and the potential need for a flushing event:

- The salt level of the soil (electrical conductivity). Corn is the most salt-sensitive crop grown at the Dairy. Soil electrical conductivity (EC) values at or over 2.0 millimhos per centimeter (mmhos/cm) will significantly impact nutrient uptake, growth, and yield.

- The sodium level of the soil. A soil is considered to be sodic when sodium makes up 15 percent or more of the cation exchange capacity. However, in practice, soils with sodium levels of 7 to 8 percent of the cation exchange capacity begin to result in negative effects on the field. It is important to note that soils high in sodium are not always associated with soils high in salts, but in most instances, they are related.

- The sulfate level of the soil. Sulfate is a key component of salt accumulation in agricultural fields.

- Visual observation. Field observations and crop yield information can be used to evaluate salt accumulation. If visual symptoms of elevated salts such as wilting and stunted growth are observed, then salt accumulation should be further evaluated.

As noted earlier, large-scale salt flushing is typically not needed if careful management of irrigation water and nutrient application is performed. However, in the event that the need for salt flushing is required, the following process would be employed at the Dairy:

- Fields with nitrate concentrations less than 45 parts per million (ppm) in the 12 to 24 inch interval would not likely present a potential issue to groundwater if flushing was performed.

- Fields with nitrate concentrations greater than 45 ppm in the 12 to 24 inch interval would require greater planning to ensure that potential impacts to groundwater did

not result from flushing activities. Soil moisture conditions measured as part of this IWMP would be used to develop an irrigation rate that would be calculated to push salts below the active root zone without resulting in significant water movement beyond the 36-inch interval.

Regardless of the soil nitrate concentrations, if a need for salt flushing is identified for any of the Dairy's irrigated cropping fields, the Dairy will develop a salt flushing plan in consultation with the professional irrigation consultant to ensure that the potential risk to underlying groundwater resulting from the flushing event is minimized. This plan will be shared with EPA for review prior to initiation of any salt flushing activity.

1.2.5 Irrigation Water Orders and Delivery

The Dairy obtains irrigation water from the local irrigation districts. Water orders are determined on a volume basis for the week based on the crop water needs. The water orders are placed with the irrigation district Water Master. The Water Master works with the Dairy to determine at what volumes and what timing irrigation water delivery will occur. The Water Master then relays the water order to the Ditch Riders who fulfill the water order by metering a certain amount of water over a certain amount of time through adjustments to gates and valves within the appropriate canals and laterals within the irrigation system. Once a water order is placed with the irrigation district and the Ditch Riders begin delivery, changes to the water order cannot be made. Automatic shutoff or refusal to take a water order is not allowed as this would significantly disrupt the overall irrigation district and could result in significant damage to the infrastructure of the system and property of other district water users and the community at large. For this reason, the irrigation districts do not allow for the use of automated shutoff systems on irrigation systems that draw water from the district.

Section III.F.2 of the AOC SOW states that the IWMP will include "the installation of electronic sensors at the bottom of the root zone in each application field to provide for automatic shut off of the irrigation system." Based on the restrictions on water delivery and ordering, automatic shutoff of the irrigation system identified in Section F.2 of the AOC SOW is not an option for the IWMP. Therefore, soil moisture monitoring data will be evaluated to coincide with water delivery and ordering. While this does not meet the automatic shutoff requirement identified in the AOC SOW, it does provide a method for the Dairy to respond to elevated soil moisture conditions that could potentially result from the over-application of irrigation water in the most rapid manner available given infrastructure constraints.

1.2.6 Nutrient Application

Nutrients are added to cropping fields at agronomic rates to provide for the nutrient requirements of the specific crops to achieve desired crop yields. Nutrient requirements are determined by the nutrient needs of the crop and current nutrient conditions within the root zone of the soil in each field. In order to determine nutrient conditions in the root zone soils, soil samples are collected from each field associated with the Dairy in accordance with the Dairy's current Nutrient Management Plan (NMP) and the Dairy's Agricultural Field Management Plan (AFMP) (ARCADIS, 2013).

Agricultural field soil sample results are used to determine current nitrogen concentrations in rooting zone soils. These nitrogen concentrations are then compared to the crop nutrient requirements to determine the nutrient needs of the crop and to develop an agronomic rate of fertilizer application to achieve crop yield goals. A more complete description of the methods and calculations used to develop agronomic rates of fertilizer application to agricultural fields associated with the Dairy can be found in the Dairy's AFMP.

Liquid manure at the Dairy is tested in accordance with the AFMP to determine its nitrogen concentration. For the purpose of determining liquid manure application rates, the liquid manure nitrogen concentration is converted from milligrams per liter (mg/L) to pounds of nitrogen per 1,000 gallons to facilitate the determination of application volumes and rates per acre. For example, if the liquid manure has a nitrogen content of 3 pounds per 1,000 gallons and the crop agronomic nitrogen need (crop nitrogen need minus current soil nitrogen concentration) is found to be 30 pounds of nitrogen per acre, then 10,000 gallons of liquid manure per acre would be needed to achieve the agronomic application rate.

Liquid manure application at the Dairy is typically performed via top-dressing prior to planting. Top-dressing application is performed primarily by using tanker trucks and irrigation systems. For tanker truck application, the tanker trucks are filled with liquid manure from the liquid manure lagoons. The trucks are then driven over the field surface and the liquid manure is applied from the tanker at a set rate given a set driving speed to meet the application requirement. Typically, efforts are made to complete application in one pass; however multiple passes may be required to avoid application rates that could exceed the soil's infiltration capability and potentially result in runoff (Cow Palace, 2008). Top-dressing using the existing irrigation systems in the field is accomplished by pumping liquid manure from the lagoons through the irrigation system. If the solids content of the liquid manure is sufficiently high that plugging or

fouling of sprinkler heads may occur, then the liquid manure may be mixed with irrigation water. Typically, the liquid manure/irrigation water mix ratio is 1:1, but may be adjusted depending on the solids content of the liquid manure. The mix ratio is measured using flow meters that record irrigation water and liquid manure inputs as they are fed to the irrigation system.

In addition to top dressing, liquid manure may be applied to fields during active growing conditions to support accelerated plant growth requirements. During the active growing season, liquid manure is delivered to fields using irrigation systems located in the field. Similar to top dressing, the amount of nitrogen needed is determined and a set volume of liquid manure is delivered to the field through the irrigation system to meet the nitrogen need and mixing of liquid manure with irrigation way may be required depending on the solids content of the liquid manure. All liquid manure volumes applied to the fields using the irrigation systems during the irrigation season are accounted for in the nutrient needs determined by soil sampling under the NMP and AFMP and the irrigation water needs for the crop determined under this IWMP.

The irrigated fields (described below in Section 1.2.7) included in this IWMP coincide with the sampling units (SUs) identified in the AFMP. Use of the same SU designation between this IWMP and the AFMP provides the opportunity for each program to inform and compliment the other while providing consistency across each plan's goals and objectives. It is anticipated that the close coordination between the two plans will result in effective nutrient and irrigation water application to the fields that will result in achieving cropping objectives and minimize the potential for irrigation water that may contain nitrogen to move past the crop root zone. In the event that either AFMP or IWMP SUs may need to be changed to account for needed management changes in nutrient application, cropping, and/or irrigation practices that could potentially impact the management of nutrients or irrigation water at the Dairy, both the AFMP and IWMP will require revision or amendment. If an amendment or revision to either of the plans is required, this will be accomplished in accordance with EPA guidance (EPA QA/G-5 and EPA QA/R-5) and will require review and approval of EPA.

1.2.7 Dairy Irrigated Fields

The seven irrigated fields at the Dairy are shown together on Figures 2A (aerial photograph base) and 2B (USGS 7.5-minute quadrangle base) and individually on Figures 3 through 9. A summary of the field conditions and soil types based on information provided by the Natural Resources Conservation Service Web Soil Survey

is presented in Table 1. The information in Table 1 was used as the basis for data collection planning and monitoring design discussed later in this IWMP.

There are five different soil types present in the irrigated fields located at the Dairy based on review of the *Soil Survey of Yakima County Area Washington* (USDA Soil Conservation Service, 1985) the Natural Resources Conservation Service Web Soil Survey. The soil types present include:

- Esquatzel Silt Loam – USCS classification: ML. Very deep, well-drained soils on flood plains, formed in silty alluvium. Moderate permeability. High available water capacity.

- Finley Silt Loam – USCS classification: ML/SM (shallow), increasing sand and gravel with depth. Very deep, well-drained soils on terraces and alluvial fans, formed in old alluvium. Moderately rapid permeability. Moderate available water capacity.

- Scoon Silt Loam – USCS classification: ML, SM, GM. Shallow (typically less than 16 inches to hardpan), well-drained soils on uplands, formed in loess overlying hardpan. Permeability is moderate above the hardpan and very slow through the hardpan. Low available water capacity.

- Shano Silt Loam – USCS classification: ML. Very deep, well-drained soils on uplands formed in loess. Moderate permeability. High available water capacity.

- Warden Silt Loam – USCS classification: ML. Very deep, well-drained soils, formed in lacustrine sediment with a mantle of loess. Moderate permeability. High available water capacity.

Figures 3 through 9 show the seven irrigated fields that are part of the IWMP. The approximate locations of the various soil types present in each field are shown on the figures. It should be noted, that the soil boundaries presented in Figures 3 through 9 are approximate as they were taken from the larger scale soil survey for the region. Where necessary, inferences regarding the location of the various soil types were made based on experience with the fields, geomorphic controls, and the presence of the various soil types within the fields. Therefore, in the individual field descriptions below, the location of topographic features and the soil type associated with the feature may not reflect the exact locations shown on the figures.

A brief summary description of the soil types and topography of each of the seven irrigated fields located at the Dairy is provided below:

- CP-SU-1 (Figure 3, soil type boundaries are slightly offset): Located to the south of the Cow Palace Dairy and west of Arms Road. The field is approximately 69 acres and is irrigated using a linear irrigation system. Soil types present include:

  - Warden silt loam
  - Scoon silt loam
  - Shano silt loam
  - Finley silt loam

  The general slope of the field is to the south. A "Y"-shaped topographic depression is present in the field in the eastern portion of the field with one branch of the "Y" extending to the northwest and the other oriented north-south. Soil types within the low lying area are predominantly the Finley and Shano silt loam units with Scoon silt loam in the northwest portion of the "Y".

- CP-SU-2 (Figure 4): Located at the northwest intersection of Kirks and Arms Roads south of Field CP-SU-1. The field is approximately 72 acres and is irrigated using a combination of linear and wheel line irrigation systems. Soil types present include:

  - Scoon silt loam (Limited to the northwest corner of the field)
  - Warden silt loam

  The general slope of the field is to the south. A topographic depression continuing from the field to the north is present in the field and is oriented roughly north-south. The depression exits the field to the southwest to an irrigation frost pond.

- CP-SU-3 (Figure 5): Located south of Zillah Road between Arms and Dekker Roads. The field is approximately 155 acres and is irrigated using a center pivot irrigation system. Soil types present include:

  - Finley silt loam (minor area near northwest corner of field)
  - Warden silt loam

The general slope of the field is to the southwest. A topographic depression is present in the western portion of the field trending northeast to northwest. The soil type associated with the swale is the Warden silt loam.

- CP-SU-4A (Figure 6): Located south of CP-SU-3 to the west of Dekker Road. The field is approximately 71 acres and is currently irrigated using a wheel line irrigation system. Historically, rill irrigation has was in this field when it was planted in corn. However, this practice is discontinued. The only soil type present in the field is the Warden silt loam. The general slope of the field is to the southwest. A topographic depression is present in the field trending from approximately the northeast corner to the southwest corner of the field. A frost pond is present along the depression in the southern third of the field.

- CP-SU-4B (Figure 7): Located south of CP-SU-4A to the west of Dekker Road. The field is approximately 40 acres and is currently irrigated using a wheel line irrigation system. The only soil type present in the field is the Warden silt loam. The general slope of the field is to the southwest. A topographic depression trending roughly north-south is present near the middle of the field.

- CP-SU-5 (Figure 8): Located on the northeast corner of Zillah and Arms Roads. The field is approximately 37 acres and is currently irrigated using a wheel line irrigation system. The only soil type present in the field is the Warden silt loam. The general slope of the field is to the south. A topographic depression is present in the field extending from the northeast corner of the field to the center of the southern boundary of the field.

- CP-SU-6 (Figure 9): Located on the north side of Knowles Road between Arms and Dekker Roads. The field is approximately 85 acres and is irrigated using a wheel line system. Currently, the field is planted in corn silage and irrigated using a rill irrigation system. This practice will be discontinued following the 2013 irrigation season. Soils present in the field include:

  - Esquatzel silt loam
  - Warden silt loam

  The general slope of the field is to the south-southwest. In the eastern portion of the field, a topographic depression extends from the northeast corner to the center of the southern boundary of the field. This eastern depression is located in both

Warden silt loam and Esquatzel silt loam soils. A second topographic depression extends from the farthest north point of the field to the southwest corner of the field. This western depression is located in the Warden silt loam soil type.

1.3 Project/Task Description and Schedule (A6)

1.3.1 Project/Task Description

The scope of the IWMP includes the collection and analysis of data to enable the Dairy to manage irrigation application in agricultural fields to minimize to potential migration of irrigation water below the root zone.

Activities to be performed as part of the IWMP include:

- Instrumentation and monitoring of irrigation water and liquid manure application volumes and rates to the application fields during the active irrigation season (Section 2.2.1).
- Data collection to determine the field capacity and bulk density of soils within each field (Section 2.2.2).
- Monitoring of the volumetric water content of application field soils at the 24- to 36-inch interval during active irrigation (Section 2.2.3).
- Weekly calculation of irrigation water needs for each field during the active irrigation season, placement of water orders to match the calculated water needs, and application of irrigation liquids at rates consistent with the water needs for the field (Sections 2.1.2 and 2.1.3).

1.3.2 Project Schedule

Task	Start Date	Completion Date
Instrumentation of Irrigation Liquid Systems	Upon EPA Approval of the QAPP	5 days prior to the initiation of irrigation activities
Field Capacity Soil Testing	Upon EPA Approval of the QAPP	60 days following initiation of testing (weather dependent)
Field Capacity Soil Testing Technical Memorandum	Upon completion of Field Capacity Soil Testing	45 days following completion of Field Capacity Soil Testing
Installation of Volumetric Water Content Sensors	Upon completion of Field Capacity Soil Testing	45 days following completion of Field Capacity Soil Testing
Weekly Irrigation Water Needs Calculation	Upon initiation of irrigation season	End of irrigation season

1.4 Quality Objectives and Criteria (A7)

1.4.1 Project Quality Objectives

Project-specific DQOs were identified through the DQO process (EPA 2006) to meet the data user's needs for each activity. The specific data needs for Irrigation Water Management focus on the collection of physical data necessary to determine the field capacity and bulk density of soils in the agricultural fields and to monitor and control volumes of liquid application to the fields. The DQO decision-making process for Irrigation Water Management is presented in Appendix A.

1.4.2 Measurement Performance Criteria

Measurement performance criteria are often expressed in terms of data quality indicators. The principal indicators of data quality are precision, accuracy, representativeness, comparability, and completeness (PARCC criteria). The following are definitions for the assessment of data quality indicators summarized from "Guidance for Quality Assurance Project Plans (EPA QA/G-5) (EPA 2002):

- **Precision** is the measure of agreement among repeated measurements of the same property under identical or substantially similar conditions and is calculated as either the range or standard deviation.

- **Accuracy** is a measure of the overall agreement of a measurement to a known value. It includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations.

- **Representativeness** is a qualitative term that expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process conditions, or an environmental condition.

- **Comparability** is a qualitative term that expresses the measure of confidence that one data set can be compared to another and can be combined for the decision to be made.

- **Completeness** is a measure of the amount of valid data needed to be obtained from a measurement system.

As part of the IWMP, soil samples will be collected and analyzed to determine the soil moisture content and bulk density. Theses parameters will be used to determine the field capacity of the soils of interest (Section 2.1.1) and to act as calibration points for volumetric water content sensors. American Society for Testing and Materials (ASTM) standard methods will be used to collect and analyze the samples. The ASTM standard methods identify that there are no applicable PARCC criteria for the sample collection and analysis methods due to the heterogenous nature of soil and rock materials that may be tested by these methods. Therefore, in order to evaluate the performance of the analysis, a minimum of three samples will be collected and analyzed at each sampling location and the average value be used for all calculations required as part of the this plan. To further evaluate the performance and reliability of this analysis, the results will be compared with literature values for similar soil types to evaluate the representativeness of the data. The three individual samples collected from each location will also be compared to each other to evaluate the precision of the method and results.

1.5 Special Training/Certification (A8)

Agrimanagement will prepare a site-specific Health and Safety Plan (HSP). The Site Safety Manager will ensure that this plan conforms to ARCADIS requirements and

project objectives. All personnel working on the project site will be trained in health and safety in accordance with the HSP. All personnel will comply with the requirements included in the HSP regarding site-specific hazards and conditions. Training requirements, documentation, and tracking are included in the HSP.

1.6 Documents and Records (A9)

All field activities will be documented in field notebooks and the appropriate field forms included in Appendix B. Field documentation may include, but is not limited to:

- Soil sample collection field sheets
- Soil sample analysis sheets
- Flow meter logs

All field team-generated documentation will be compiled and submitted to the STL and PC for distribution, inclusion in the project records, and use in subsequent reporting.

2. Data Generation and Acquisition (Group B)

2.1 Evaluation Design (Experimental Design) (B1)

The Irrigation Water Management design was developed using the DQO process (Appendix A) to ensure that the appropriate types, quantity, and quality of data are collected to answer the principal question of the IWMP. The principal question of the IWMP is:

> "Is the method of irrigation water application management presented in the IWMP sufficient to minimize the potential movement of irrigation water below the root zone within application fields at the Dairy?"

In order to address the principal question, the soil field capacity (Section 2.1.1) and volumetric water content (Section 2.2.3) at the 3 feet below ground surface interval need to be known. These values will be compared to each other to determine the appropriate action.

The potential outcomes of the principal question are:

- No action
- Adjust irrigation rates and/or methods

Based on the principal question and potential outcomes, the following decision rules were developed to guide irrigation water management under this IWMP:

- If the volumetric water content (VWC) measured at the 3 feet below ground surface (ft bgs) interval for the prior week is equal to or less than the soil field capacity (FC), then current irrigation water management is achieving the objective of the IWMP and a water order from the irrigation district will be made in accordance with the professional irrigation consultant's recommendation.

- If the VWC measured at the 3 ft bgs interval for the prior week is greater than the soil FC, then the Dairy will implement changes to the irrigation program for the SU (field) in accordance with the professional irrigation consultant's recommendation that may include changes to irrigation application rates, reduction in the water order, changes to irrigation methods, or other changes that are anticipated to result in a VWC at the 3 ft bgs interval that will be equal to or less than the soil FC.

The data collection and evaluation strategy developed for this IWMP has been designed to ensure that appropriate methods are used to develop irrigation application rates and volumes that are anticipated to prevent saturation of soils in irrigated cropping fields below the root zone while meeting agricultural objectives. Evaluation of soil moisture conditions on a weekly basis, to coincide with irrigation water orders, is included in the IWMP to evaluate the effectiveness of the irrigation application rates developed as part of the IWMP, inform the development of water orders, and to allow actions to be taken to address conditions that may result in the potential for migration of irrigation water below the root zone, if necessary.

2.1.1 Soil Field Capacity and Bulk Density

The field capacity of a soil is defined as the amount of water held in the soil 24 to 72 hours following a saturation event (soil pore space completely filled with water) after excess gravitational water has drained away (Veihmeyer and Hendrickson, 1931). Therefore, field capacity represents the amount of moisture that a soil can retain without downward movement of water due to gravity.

Field capacity is a commonly used agricultural soil parameter employed to identify the amount of water that a soil can retain that is available to plants without losses due to downward migration resulting from gravity. The field capacity concept was developed to encourage farmers not to irrigate excessively, but rather to take advantage of the soil water reservoir. Given that field capacity is less than saturation and represents a relatively steady state condition for moisture in soil, it provides a conservative comparison point for identification of soil moisture conditions that could potentially result in movement of water below the root zone.

As stated in the project decision statements, the VWC collected from sensors installed at the 3-foot interval will be compared with the soil field capacity to evaluate the objective of the IWMP. In order to calibrate the VWC sensors and to provide the soil field capacity comparison point, the soil field capacity and soil bulk density will be determined from the field capacity soil samples (Section 2.2.2).

The soil field capacity will be calculated for each sensor location and depth interval included in the IWMP. Field capacity soil samples will be collected and analyzed in accordance with the methodology presented in Sections 2.2.2 and 2.4. A total of three individual samples will be collected at each location and depth interval and the average value of field capacity from the samples will be used as the field capacity value for that location and depth interval.

- The moisture content of the field capacity soil samples collected using the methods described in Section 2.2.2 will represent the soil field capacity. The following equation will be used to calculate the field capacity by volume for each sample:

$$FC = (V_{water} / V_{wet}) \times 100$$

  Where:

  - FC = field capacity of soil by volume (percent)
  - V_{water} = volume of water in the sample (cm^3)
  - V_{wet} = volume of the wet sample (cm^3), determined during sample collection
  - 100 = conversion factor from ratio to percent

- In order to calculate the volume of water in the field capacity sample (V_{water}), the following equation will be used:

$$V_{water} = M_{water} / \rho_{water}$$

Where:

  - V_{water} = volume of water in the sample (cm^3)
  - M_{water} = mass of water in sample (g)
  - ρ_{water} = density of water (1 g/cm^3)

- M_{water} will be determined after oven drying the sample by the following equation:

$$M_{water} = M_{wet} - M_{dry}$$

Where:

  - M_{water} = mass of water in sample (g)
  - M_{wet} = mass of wet sample (g)
  - M_{dry} = mass of dry sample (g)

- The soil bulk density will be calculated using the following equation:

$$\rho_{soil} = M_{dry} / V_{wet}$$

Where:

  - ρ_{soil} = soil bulk density (g/cm^3)
  - M_{dry} = mass of dry sample (g)
  - V_{wet} = volume of wet sample (cm^3)

- V_{wet} will be determined during sample collection by the following equation:

$$V_{wet} = (\pi r^2 L) \times 16.4$$

Where:

- V_{wet} = volume of wet sample (cm^3)
- r = the inner radius of the soil sample collection device (inches)
- L = the length of the soil sample collection device (inches)
- 16.4 = conversion factor between cm^3 and in^3

2.1.2 Irrigation Water Need Calculation

The need for Irrigation water will be determined on a SU basis. In addition to the 3-foot interval volumetric water content (VWC) sensors, VWC sensors will be installed at the 1- and 2-foot intervals in at least one location in each SU. The data from these sensors will be used to evaluate the crop water needs that will act as the basis for the weekly water order. If the VWC measurements from sensors located at the 3-foot interval in the SU are less than their respective FC, then the following method will be used to determine the irrigation water need for the crop:

1. Determine Wilting Point (WP):
    a. The wilting point (WP) represents the soil moisture content of soils at which plants are no longer able to access water from the soil and wilting occurs from which the plants will not recover.
    b. The following equation is used to determine WP:
        i. WP = 0.28 × FC
        ii. Where:
            1. WP = Wilting point (percent, volumetric)
            2. 0.28 = Wilting point factor for silt loam soils (Saxton and Rawls, 2006)
            3. FC = Field capacity (percent, volumetric)

2. Convert FC, WP, and VWC (from sensor) to inches:
    a. (FC, WP, or VWC) / 100 × 12 = FC, WP, or VWC in inches
    b. Where:
        i. FC, WP or VWC – water content values (volumetric) in percent
        ii. 12 = conversion factor to inches of water in 1 foot of soil

3. Calculate Available Water Content (AWC):
    a. The AWC represents the amount of water in 1 foot of soil that is available to plants.
    b. The following equation is used to determine AWC:
        i. AWC = VWC – WP
        ii. Where:
            1. AWC = available water content (inches)
            2. VWC = volumetric water content (inches)
            3. WP = wilting point (inches)

4. Calculate percent available water (%AW):
    a. %AW represents the percent of water available to plants represented by the VWC, assuming that the FC minus unavailable water (WP) is the maximum amount of water available.
    b. The following equation is used to determine %AW:
        i. %AW = (VWC – WP) / (FC – WP)
        ii. Where:
            1. %AW = percent available water (percent)
            2. VWC = volumetric water content (percent)
            3. WP = wilting point (percent)
            4. FC = field capacity (percent)

5. Calculate the water content (WC):
    a. The following equation is used to determine WC:
        i. WC = %AW × AWC
        ii. Where:
            1. WC = water content (inches)
            2. %AW = percent available water (percent)
            3. AWC = available water content (inches)

6. Calculate water depletion (WD):
    a. The following equation is used to determine WD:
        i. WD = AWC – WC
        ii. Where:
            1. WD = water depletion (inches)
            2. AWC = available water content (inches)
            3. WC = water content (inches)

7. Determine crop water need:
    a. The following equation is used to determine the crop water need:
        i. CWN = WD + (weekly ET × K_C)
        ii. Where:
            1. CWN = weekly crop water need (inches
                a. Water depletion will depend upon the specific crop rooting depth.
            2. WD = water depletion (inches)
            3. Weekly ET = weekly evapotranspiration (inches) from AgWeatherNet weather station converted from single day to 7 days.
            4. K_C = crop coefficient (unitless) from AgWeatherNet and AgriMet depending on crop
            5. If precipitation is forecasted, the amount of precipitation will be subtracted from the CWN.

The crop water need will be equal to the amount of irrigation water needed to support crop plant growth during the week. Calculations for the crop water need will be derived for each depth separately and presented as a total water deficit or surplus based on (1) a full 3-foot profile basis (or to the depth attainable) and (2) a specific crop rooting depth basis. This value will be provided in the number of inches of water that will need to be applied over the week to the field. Because the crop water need calculations are based on the FC being the maximum amount of water that is allowed to be present in the soil column, the potential for downward migration of irrigation water below the root zone is minimized. If VWC measurements at the 3-foot interval approach or exceed the FC, then the crop water need calculations will be revisited and application volumes and rates will be adjusted accordingly to ensure that irrigation water application is not resulting in the elevated VWCs.

2.1.3 Water Order

The irrigation water need for each of the seven irrigated fields will be calculated as the CWN as described in Section 2.1.3 by the irrigation professional. The CWN value for each field will be provided to the Dairy. The Dairy will contact the local irrigation district Water Master to place the water order that will meet the irrigation water need for the Dairy based on the total irrigation need, acreage, and delivery considerations and options.

2.2 Data Collection Methods (B2)

This section presents the data collection methods that will be used for the collection of required inputs to perform calculations and monitor soil moisture and irrigation liquid application rates at the Dairy.

2.2.1 Flow Meter/Totalizer Operation

All piping delivering liquids to the irrigation systems at the Dairy will be fitted with flow meters or totalizers depending on pipe sizing and properties of the liquid. All meters and totalizers will be located upstream of the irrigation systems and will be read on a weekly basis while irrigation systems are in operation. At the end of each week, irrigation liquid volumes will be checked against water need calculations (Section 2.1.2).

2.2.2 Soil Field Capacity and Bulk Density Data Collection

Soil samples will be collected in order to calculate the soil field capacity at each location where sensors are to be installed (Section 2.2.3). The following protocol will be used for the collection of soil field capacity samples:

1. At each sensor location, a 12-inch diameter hole will be hand excavated to a depth of 24 inches. Care will be taken to avoid disturbing the soil located below 24 inches.

2. The 12-inch diameter, 24-inch deep hole will be filled with to a depth of 6 inches with water.

3. Following filling with water, the hole will be covered with plastic to prevent evaporation and the plastic will be anchored to prevent it from blowing away and uncovering the hole.

4. The field team will return between 24 and 48 hours after Step 3 to collect soil samples.

5. After uncovering the hole, visually observe the bottom of the hole. If standing water is observed, recover the hole and return in 24 hours. If there is no standing water, then soil samples may be collected.

6. Collect 3 soil samples from near the center of the hole without overlapping. Soil samples will be collected using a 1-inch inner diameter, 12-inch long soil sample collection device.

7. Drive the sample collection device near the center of the hole to a depth of 12 inches.

8. Withdraw the sample collection device from the hole and open the sample probe.

9. Record the sample collection device length on the field data sheet in inches.

10. Place the sample in an individual pre-weighed, and pre-labeled air-tight soil sample can and seal the lid and label the sample as described in Section 2.5.

11. Repeat steps 7 through 10 until 3 samples have been collected from the hole.

12. Place the sample can in the designated sample container for transport to the Agrimanagement office for analysis.

This protocol will be followed at each location where a sensor has been identified for placement.

In each of the seven fields, the Dairy is placing additional soil sensors in 1 location per field at the 1- and 2-foot intervals to provide additional data for the development of irrigation water application rates to maximize crop yields and to provide information to the professional irrigation consultant regarding soil moisture conditions in the root zone. While it is anticipated that these sensors will provide valuable information regarding soil moisture conditions, they will not be used to evaluate the overall objective of the IWMP. Field capacity soil samples will be collected for these locations as well using the same methodology identified above with the following exceptions:

- 1-foot interval sensors – an 8-inch tall berm will be constructed around a 12-inch diameter area on the ground surface using field soils or a plastic or metal ring.

- 2-foot interval sensors – the 12-inch diameter hole will be excavated to a depth or 12 inches.

2.2.3 Volumetric Water Content Monitoring

Volumetric water content monitoring will be performed by placing Decagon EC-5 sensors installed at 3 ft bgs at select locations in each field. Manufactures information, including operation and maintenance, of the EC-5 sensor is included in Appendix C. The sensors measure the dielectric permittivity (capacitance) of the soil which is converted into a volumetric water content by the Decagon software. All sensors will be set to record the volumetric water content on an hourly basis. Sensor information will be recorded using an Em50 Series Data Collection System (Appendix D) and will be downloaded on at least a weekly basis. The data will be downloaded and analyzed (Section 2.1.2) prior to the Dairy placing the weekly water order with the irrigation district.

The number and location of volumetric water content monitoring sensors focuses on areas within each field that may be the most susceptible to the migration of irrigation water below the crop root zone (such as low-lying areas within soils with the greatest permeability). The number of sensors identified for placement in each field is based on the location and type of susceptible areas as well as the irrigation method being used in that field. The number and proposed locations of sensors for each field are presented in Figures 3 through 9 and are summarized by field below:

- CP-SU-1 (Figure 3): A total of 3 sensors will be placed in CP-SU-1.
  - Near the northeast corner of the field in the depression (Warden silt loam)
  - In the southern portion of the depression (Finley silt loam)
  - In the southwest corner of the field (Warden silt loam)
  - No sensor was identified for placement in the northwest-southeast trending arm of the depression as this area is comprised of Scoon silt loam which only extends 16 inches before hard pan.
- CP-SU-2 (Figure 4): Two sensors will be placed in CP-SU-2.
  - In the southern portion of the depression (Warden silt loam)
  - Near the northwest corner of the field (Warden silt loam)

- CP-SU-3 (Figure 5): Three sensors will be placed in CP-SU-3. Only one soil type is present over the majority of the field (Warden silt loam). The sensors will be placed in near the beginning, middle, and end of the radius of center pivot irrigation system. The middle and end sensors will be placed in the north-south trending depression.

- CP-SU-4A (Figure 6): Two sensors will be placed in CP-SU-4A. Only one soil type is present in CP-SU-4A (Warden silt loam). The sensors will be placed near the southern end of the northeast-southwest trending depression below the frost pond and in the center of the western portion of the field.

- CP-SU-4B (Figure 7): Two sensors will be placed in CP-SU-4B. Only one soil type is present in the field (Warden silt loam). One sensor will be placed along the northern portion of the north-south trending depression and the other will be placed in the northwest quadrant of the field.

- CP-SU-5 (Figure 8): Two sensors will be placed in CP-SU-5. Only one soil type is present in the field (Warden silt loam). One sensor will be placed in the north-south trending depression. The other will be placed in the southwest quadrant of the field.

- CP-SU-6 (Figure 9): Three sensors will be placed in CP-SU-6.

  - In the northern portion of the field in the western depression (Warden silt loam)
  - In the middle of the field (Warden silt loam)
  - In the eastern depression (Esquatzel silt loam)

The following procedure will be used for the installation of the Decagon EC-5 sensors:

1. Move to a location near where the field capacity sample for each location was collected. Document the sensor location with GPS coordinates.

2. Auger or dig a hole to 36 inches

3. Label and install the sensor in the soil profile using a tape measure. Install the sensor in the undisturbed sidewall of the hole.

4. After sensor placement, backfill, tamp, and return the soil surface to as near the original state and elevation as possible.

5. Place a post or pipe at least 5 feet from the sensors and mount the data logger and attach the sensor cable to the data logger.

6. Install the rain gauge on the data logger post and connect to the data logger.

7. Create a trench (deep enough to avoid damage from farm machinery) between the sensor location and the post; place the sensor cable in the trench, and; backfill the trench.

8. Set the data logger to record volumetric water content on an hourly basis.

2.3 Sample Handling and Custody (B3)

This section describes sample management and documentation procedures that will be followed during soil sampling activities conducted under this IWMP. All soil samples collected under this IWMP will remain in the custody of Agrimanagement personnel and will be transported directly from the field to the Agrimanagement offices located at 408 North 1st Street, Yakima, Washington. All samples collected as part of the IWMP will be recorded on the soil sampling field forms and in field notebooks as applicable.

2.4 Analytical Methods (B4)

Soil samples collected as part of this IWMP will be tested at the Agrimanagement offices for:

- Water content by ASTM D2216-10 *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*, and;
- Bulk density by ASTM D2937-10 *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method*.

2.5 Quality Control (B5)

No quality control soil samples will be collected as part of the IWMP soil sampling. As noted in Section 1.4.2, no PARCC criteria or standards are available to evaluate method performance.

A sample for water content and bulk density will be collected and analyzed from each particular sensor location in a given SU. The sample results for a given SU will be compared to one another and the average of the three results will be compared to literature values for similar soils.

All samples collected as part of the IWMP soil sampling will be assigned a unique sample number. Samples will be labeled as follows:

CP-SU-X-Y-Z

Where:

- X = the irrigated field SU number (1, 2, 3, 4A, 4B, 5, or 6)
- Y = the sensor location (1, 2, 3, etc.)
- Z = A, B, or C for each of the three sample depths collected from each location

All samples in containers will be placed in a sample collection box or cooler where they are protected from damage.

2.6 Instrument/Equipment Testing, Inspection, and Maintenance (B6)

All instruments and equipment used as part of this IWPM will be tested, inspected, and maintained in accordance with manufacturer instructions and SOPs.

2.7 Instrument/Equipment Calibration and Frequency (B7)

All instruments and equipment used as part of this IWMP will be calibrated in accordance with and at the frequency indicated in the manufacturer instructions and SOPs.

2.8 Inspection/Acceptance of Supplies and Consumable (B8)

Supplies and consumables that may be used during implementation of this IWMP will be inspected by ARCADIS, Agrimanagement, and/or Dairy personnel upon receipt.

2.9 Non-direct Measurements (B9)

No pre-existing data will be used to make decisions in support of this IWMP. All data used to support decision-making will be collected during the implementation of the Irrigation Water Management Plan.

2.10 Data Management (B10)

All field data collected as part of this IWMP will be recorded on field forms as discussed in previous sections and included in Appendix B. Data collected from volumetric water content sensors will be downloaded, plotted, and interpreted to determine water needs and application rates on a weekly basis prior to ordering water delivery for the following week. The electronic data will be submitted to EPA when downloading, plotting, interpreting, and calculating water needs is completed each week. Data submitted to EPA will be in raw format in an Excel spreadsheet or similar electronic data management tool, in plotted format, and appropriate calculations used to determine water needs will be included.

3. Assessment and Oversight (Group C)

3.1 Assessments and Response Actions (C1)

The PC and QAM will monitor the performance of the QA procedures presented in this QAPP. The PC has the ultimate responsibility for implementation of this QAPP. If problems arise, or if directed by the PC, the QAM will conduct a field audit for the purpose of evaluating compliance with the guidance presented in this QAPP.

3.2 Reports to Management (C2)

A Dairy Field Capacity Soil Testing Memorandum will be generated following the completion of the field capacity soil sampling and data evaluation. The Dairy Field Capacity Soil Testing Technical Memorandum will provide a summary of field activities and field capacity testing results. Data report examples are presented in Appendix F.

Data collected from volumetric water content sensors will be downloaded, plotted, and interpreted to determine water needs and application rates on a weekly basis, for all fields where active irrigation is occurring, prior to ordering water delivery for the following week. The electronic data will be submitted to EPA when downloading, plotting, interpreting, and calculating water needs is completed each week. Data

submitted to EPA will be in raw format in an Excel spreadsheet or similar electronic data management tool, in plotted format, and appropriate calculations used to determine water needs will be included.

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5. Certifications

5.1 Cow Palace Certification

I certify under the penalty of law that this document and all attachments were prepared by me or under my direction or supervision in accordance with a system designed to assure that qualified personnel gathered and evaluated the information submitted. Based on my inquiry of any and all persons directly responsible for gathering and analyzing the information obtained, I certify that the information contained in or accompanying this submittal is to the best of my knowledge and belief, true, accurate and complete. As to those identified portion(s) of this submittal for which I cannot personally verify the accuracy, I certify that this submittal and all attachments were prepared in accordance with procedures designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those directly responsible for gathering the information, or the immediate supervisor of such person(s), the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Cow Palace LLC

Signature: **DRAFT DOCUMENT**

Name: Adam Dolsen

Title: Member

Date: _____

ARCADIS

Tables

Table 1
Sampling Unit Summary
Cow Palace Dairy, Yakima County, Washington

Sampling Unit Designation	Related Application Field	Field Size (Acres)	Irrigation Type	Soil Series Present in Sampling Unit [1]	Prevalence in Sampling Unit [2] (Approximate)	
					Acres	Percent
CP-SU-1	Field 1	69	Linear	Warden silt loam, 2 to 5 percent slopes	24.7	35.7%
				Warden silt loam, 5 to 8 percent slopes	13.8	20.0%
				Scoon silt loam, 5 to 8 percent slopes	12.8	18.6%
				Scoon silt loam, 2 to 5 percent slopes	6.6	9.5%
				Shano silt loam, 8 to 15 percent slopes	5	7.3%
				Finley silt loam, 2 to 5 percent slopes	3.7	5.4%
				Scoon silt loam, 8 to 15 percent slopes	2	2.9%
				Warden silt loam, 8 to 15 percent slopes	0.3	0.4%
				Warden silt loam, 15 to 30 percent slopes	0.1	0.2%
CP-SU-2	Field 2	71.7	Linear / Wheel line	Warden silt loam, 8 to 15 percent slopes	30.8	43.0%
				Warden silt loam, 2 to 5 percent slopes	23.3	32.4%
				Warden silt loam, 5 to 8 percent slopes	11.3	15.8%
				Warden silt loam, 15 to 30 percent slopes	9.5	6.1%
				Scoon silt loam, 8 to 15 percent slopes	1.9	2.6%
CP-SU-3	Field 3	155.4	Center pivot	Warden silt loam, 2 to 5 percent slopes	127.6	82.1%
				Warden silt loam, 5 to 8 percent slopes	21.1	13.6%
				Warden silt loam, 8 to 15 percent slopes	6.7	4.3%
CP-SU-4A	Field 4A	71	Wheel line	Warden silt loam, 2 to 5 percent slopes	41	57.6%
				Warden silt loam, 5 to 8 percent slopes	25.7	36.3%
				Warden silt loam, 8 to 15 percent slopes	4.3	6.1%
CP-SU-4B	Field 4B	40.1	Wheel line	Warden silt loam, 2 to 5 percent slopes	20.3	50.7%
				Warden silt loam, 5 to 8 percent slopes	10.7	26.8%
				Warden silt loam, 8 to 15 percent slopes	9.1	22.5%
CP-SU-5	Field 5	37.1	Wheel line	Warden silt loam, 2 to 5 percent slopes	31.3	84.4%
				Warden silt loam, 5 to 8 percent slopes	5.8	15.5%
CP-SU-6	Field 6	84.9	Wheel line	Warden silt loam, 2 to 5 percent slopes	43.6	51.4%
				Warden silt loam, 8 to 15 percent slopes	21.9	25.8%
				Warden silt loam, 5 to 8 percent slopes	13.8	16.3%
				Esquatzel silt loam, 0 to 2 percent slopes	5.6	6.6%

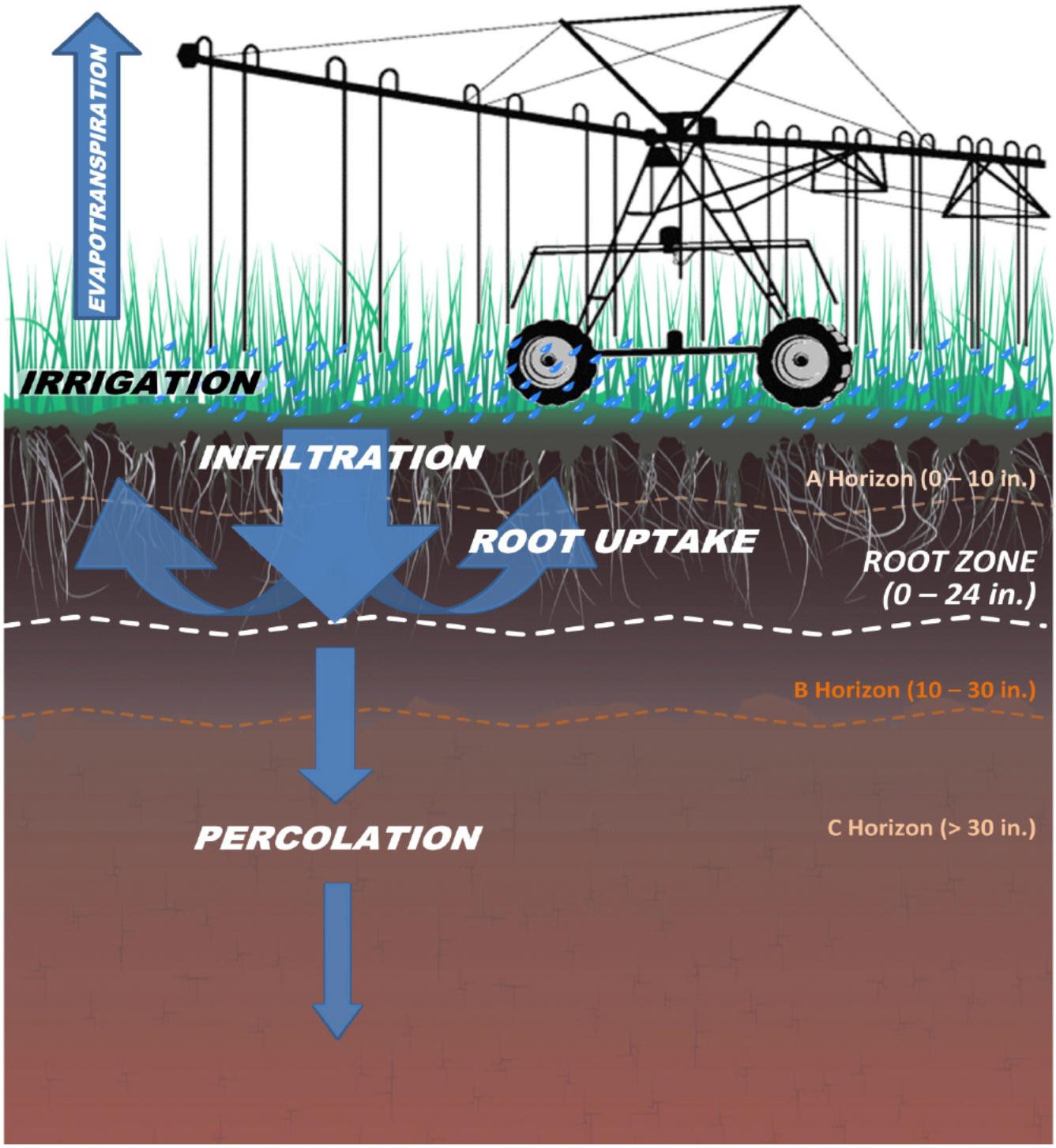
Notes:

(1) - Information obtained from Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [10/2/2013].

(2) - Soil area/prevalence measurements calculated using Web Soil Survey.

ARCADIS

Figures



Credits: © Can Stock Photo Inc. / Vertyr; © Can Stock Photo Inc. / bigredlynx ; © Can Stock Photo Inc. / basel101658

FIGURE NOT TO SCALE

NOTES:

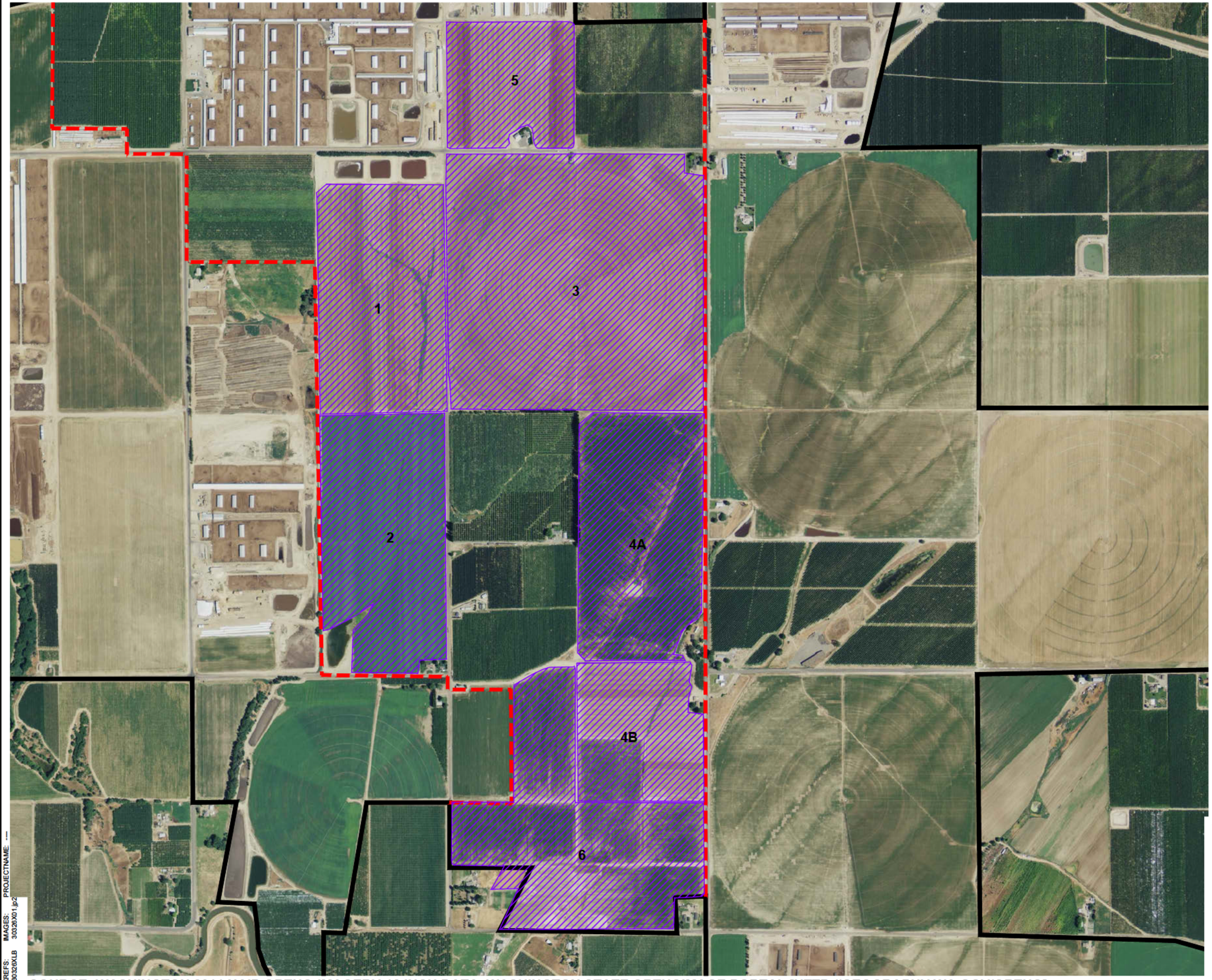
1 - Soil Horizon A - Topsoil (zone of leaching)
2 - Soil Horizon B - Subsoil (zone of accumulation)
3 - Soil Horizon C - Subsurface soil horizon consisting of soil parent material

COW PALACE DAIRY
SDWA-10-2013-0080
IRRIGATION WATER MANAGEMENT PLAN

CONCEPTUAL SITE MODEL

ARCADIS

FIGURE
1



LEGEND:

- APPROXIMATE BOUNDARY OF DAIRY FACILITIES
- COW PALACE DAIRY APPLICATION FIELDS AS "SP–SU–" FIELD NUMBER
- RESPONDENTS OWNERSHIP BOUNDARIES

0 1000' 2000'

GRAPHIC SCALE

SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

COW PALACE DAIRY
SDWA-10-2013-0080
IRRIGATION WATER MANAGEMENT PLAN

LOCATION MAP

ARCADIS

FIGURE
2A

CITY:(Reqd) DIV/GROUP:IM/OM /ENV/CAD DB:A. Schilling, R. BASSETT LD:(Opt) PIC:(Opt) PM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF*
G:\ENV\CAD\SYRACUSE\ACTISK030326\000000\11\DWG\WMP\30326B01.dwg LAYOUT: 1 SAVED: 9/3/2013 2:30 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---
XREFS: IMAGES: PROJECTNAME: ---
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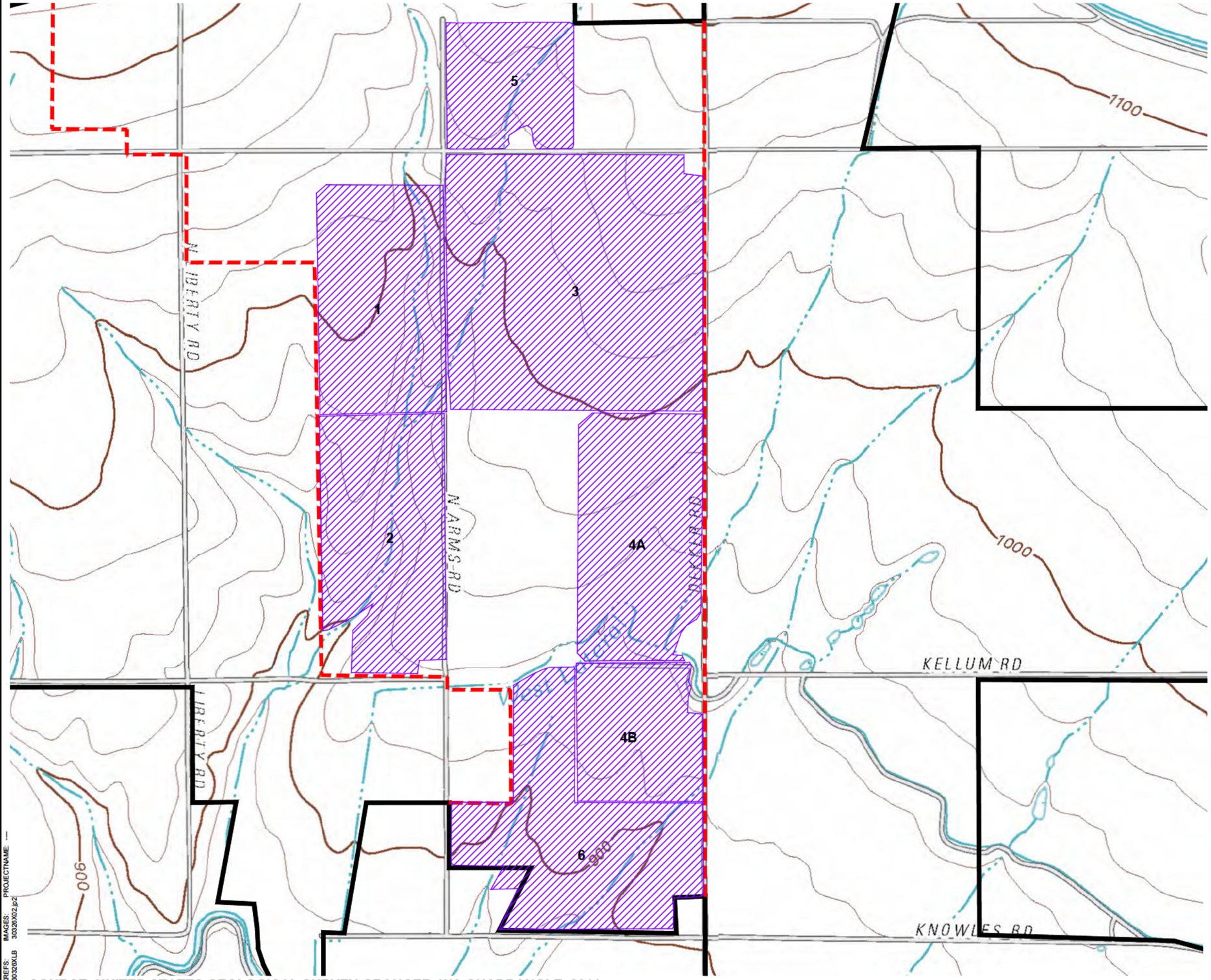

LEGEND:

- APPROXIMATE BOUNDARY OF DAIRY FACILITIES
- COW PALACE DAIRY APPLICATION FIELDS AS "CP-SU-" FIELD NUMBER
- RESPONDENTS OWNERSHIP BOUNDARIES

0 1000' 2000'

GRAPHIC SCALE

SOURCE: UNITED STATES GEOLOGICAL SURVEY;GRANGER, WA QUADRANGLE, 2011.

YAKIMA VALLEY DAIRIES
SDWA-10-2013-0080
IRRIGATION WATER MANAGEMENT PLAN

AREA TOPOGRAPHY

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FIGURE
2B

SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

0 300' 600'

GRAPHIC SCALE

LEGEND:

■	SOIL MOISTURE SENSOR
Fl2	– FINLEY SILT LOAM, 2 TO 5% SLOPES
Sc2	– SCOON SILT LOAM, 2 TO 5% SLOPES
Sc5	– SCOON SILT LOAM, 5 TO 8% SLOPES
Sc8	– SCOON SILT LOAM, 8 TO 15% SLOPES
Sh8	– SHANO SILT LOAM, 8 TO 15% SLOPES
Wa2	– WARDEN SILT LOAM, 2 TO 5% SLOPES
Wa5	– WARDEN SILT LOAM, 5 TO 8% SLOPES
Wa8	– WARDEN SILT LOAM, 8 TO 15% SLOPES
Wa15	– WARDEN SILT LOAM, 15 TO 30% SLOPES

COW PALACE DAIRY
SDWA-10-2013-0080
IRRIGATION WATER MANAGEMENT PLAN

CP-SU-1

ARCADIS

FIGURE
3

SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

0 300' 600'

GRAPHIC SCALE

LEGEND:

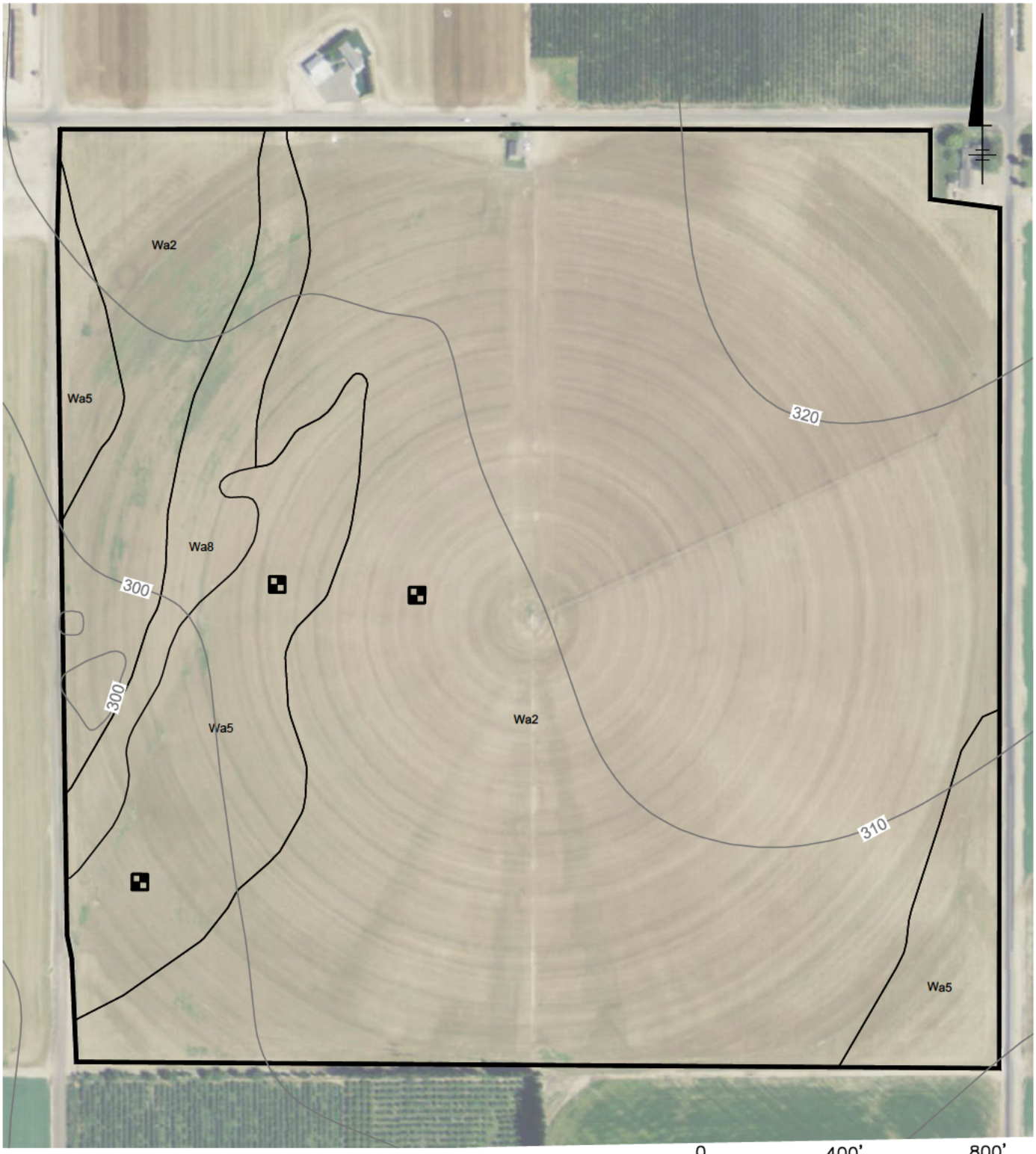
■	SOIL MOISTURE SENSOR
Sc8	– SCOON SILT LOAM, 8 TO 15% SLOPES
Wa2	– WARDEN SILT LOAM, 2 TO 5% SLOPES
Wa5	– WARDEN SILT LOAM, 5 TO 8% SLOPES
Wa8	– WARDEN SILT LOAM, 8 TO 15% SLOPES
Wa15	– WARDEN SILT LOAM, 15 TO 30% SLOPES

COW PALACE DAIRY
SDWA-10-2013-0080
IRRIGATION WATER MANAGEMENT PLAN

CP-SU-2

ARCADIS

FIGURE
4



SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

0 400' 800'

GRAPHIC SCALE

LEGEND:

- ■ SOIL MOISTURE SENSOR
- Wa2 – WARDEN SILT LOAM, 2 TO 5% SLOPES
- Wa5 – WARDEN SILT LOAM, 5 TO 8% SLOPES
- Wa8 – WARDEN SILT LOAM, 8 TO 15% SLOPES

COW PALACE DAIRY
SDWA-10-2013-0080

IRRIGATION WATER MANAGEMENT PLAN

CP-SU-3

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FIGURE 5

SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

0 400' 800'

GRAPHIC SCALE

LEGEND:

■	SOIL MOISTURE SENSOR
Wa2	– WARDEN SILT LOAM, 2 TO 5% SLOPES
Wa5	– WARDEN SILT LOAM, 5 TO 8% SLOPES
Wa8	– WARDEN SILT LOAM, 8 TO 15% SLOPES

COW PALACE DAIRY
SDWA-10-2013-0080

IRRIGATION WATER MANAGEMENT PLAN

CP-SU-4A

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FIGURE 6

SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

0 300' 600'

GRAPHIC SCALE

LEGEND:

- SOIL MOISTURE SENSOR
- Wa2 – WARDEN SILT LOAM, 2 TO 5% SLOPES
- Wa5 – WARDEN SILT LOAM, 5 TO 8% SLOPES
- Wa8 – WARDEN SILT LOAM, 8 TO 15% SLOPES

COW PALACE DAIRY
SDWA-10-2013-0080

IRRIGATION WATER MANAGEMENT PLAN

CP-SU-4B

ARCADIS

FIGURE 7

SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

0 200' 400'

GRAPHIC SCALE

LEGEND:

- SOIL MOISTURE SENSOR
- Wa2 – WARDEN SILT LOAM, 2 TO 5% SLOPES
- Wa5 – WARDEN SILT LOAM, 5 TO 8% SLOPES

COW PALACE DAIRY
SDWA-10-2013-0080

IRRIGATION WATER MANAGEMENT PLAN

CP-SU-5

ARCADIS

FIGURE 8

SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

0 400' 800'

GRAPHIC SCALE

LEGEND:

■	SOIL MOISTURE SENSOR
Es0	– ESQUATZEL SILT LOAM, 0 TO 2% SLOPES
Wa2	– WARDEN SILT LOAM, 2 TO 5% SLOPES
Wa5	– WARDEN SILT LOAM, 5 TO 8% SLOPES
Wa8	– WARDEN SILT LOAM, 8 TO 15% SLOPES

COW PALACE DAIRY
SDWA-10-2013-0080

IRRIGATION WATER MANAGEMENT PLAN

CP-SU-6

ARCADIS

FIGURE
9

Appendix A

Data Quality Objectives

Appendix A – Data Quality Objectives for the Irrigation Water Management Plan

Step 1: State the Problem	*Description of the Problem:* Section III.F.2 of the Consent Order (CO) Scope of Work (SOW) requires the Cow Palace Dairy (Dairy) to develop and implement an irrigation water management plan (IWMP) that describes "flow metering to measure the volume of liquid applied to specific fields, and the installation of electronic sensors at the bottom of the root zone in each application field to provide for automatic shut off of the irrigation system to minimize water movement below the root zone." In order to ensure that management of irrigation of the application fields occurs in a manner that minimizes the potential movement of irrigation water below the root zone, a method to monitor soil moisture conditions and irrigation water application volumes and rates is required. The monitoring method must provide sufficient measurement coverage to account for different soil types, topographic conditions, and irrigation application methods and techniques employed in each irrigated field. *Conceptual Model:* Irrigation of crop fields is performed to provide the moisture required for crop growth. Each crop has unique water requirements to achieve maximum yield based on precipitation and soil conditions. The under-application of water can result in diminished yield or failure of the crop. Over-application of water can also result in reductions in yield and crop failure, but may also result in the infiltration of excess irrigation water below the crop root zone. Careful and planned administration of irrigation water on crop land is required to maximize crop yields and to minimize potential losses of water to the subsurface below the root zone. The stage of plant growth, crop water needs, and soil properties (water holding capacity and infiltration rates), and topography control the amount of water that may be applied to application fields without the resultant migration of irrigation water below the root zone of the crop. Effective irrigation water management results in crops that receive the appropriate amount of water to achieve yield expectations and minimizes the potential for water movement below the root zone. *Irrigation System Descriptions:* A brief description of the various irrigation methods employed at the Dairy are provided below: • Center Pivot – Method of crop irrigation where a long segmented arm revolves around a pivot that delivers water through a system of sprinklers located along the arm. The size and application rate from sprinklers along the arm are designed to ensure that overall application rates across the irrigated area are equal at the segmented arm revolves (smaller sprinklers/lower application rates at the center and larger sprinklers/higher application rates toward the outer radius).

	• Linear – Method of crop irrigation where a long segmented arm (same look as a center pivot) moves in a lateral or linear fashion across a field that delivers water through a system of sprinklers located along the arm. Sprinkler sizes and application rates are generally the same across the length of the linear arm to ensure equal application rates. • Wheel Line – Method of crop irrigation where long individual pipes, with large wheels and sprinklers attached, are connected to form a long "wheel –line" that is moved laterally across a field, similar to linear irrigation. • Reel Gun – Method of crop irrigation where a traveling gun (large sprinkler) attached to a wheeled cart is placed in one location in the field and then gradually pulled back into a large hose reel. The reel is placed in designated areas to be pulled across field sections. • Rill – Method of crop irrigation where intentionally created ditches are formed to carry water from a head ditch or metered pipe. The water flows down the ditch to a collection basin or drain ditch. *Planning Team:* The IWMP was developed by a team of scientists and engineers using the systematic planning process. The planning team included the Dairy staff, a professional irrigation consultant, scientists, and engineers. The IWMP data quality objectives (DQOs) generated using the systematic planning process were shared with EPA for review, input, and approval prior to completion and finalization of the IWMP. *Resources and Schedule:* The IWMP was developed in the summer/fall of 2013 and is scheduled for implementation by the Dairy upon approval by EPA. It is anticipated that the IWMP will be fully employed prior to the initiation of irrigation activities during the 2014 growing season.
Step 2: Identify the Decision	*Principal Study Question:* Is the scientific method for irrigation water application management presented in the IWMP sufficient to minimize the potential movement of irrigation water below the root zone within application fields at the Dairy? *Alternative Outcomes:* • No action • Adjust irrigation methods and/or rates *Decision Statements:* 1. If the volumetric water content (VWC) at the 3-foot below ground surface interval within an irrigation application field does not exceed the soil field capacity (FC) on a volume or weight basis, respectively, indicating that irrigation water application volumes and rates are not resulting in near saturation of the soils and the potential for downward migration of irrigation water below the root zone, then no action is required.

	2. If the VWC at the 3-foot below ground surface interval within an irrigation application field exceeds the soil FC on a volume or weight basis, respectively, indicating that irrigation water application volumes and rates are resulting in near saturated conditions within the soils and the potential for downward migration of irrigation water below the root zone, then actions will be taken to adjust irrigation application rates and/or methods to appropriate levels to reduce VWC at the 3 foot below ground surface interval to levels at or below the FC to minimize the potential migration of irrigation water below the crop root zone.
Step 3: Identify Inputs to the Decision	*Type of information needed (source in parentheses):* • Location and size of the application field (field records/GIS) • Soil properties and types within the application field (NRCS soil survey and field observations) • Topographic data for the application field that show low lying areas, swales, and drainages (field records, USGS maps, GIS, field observations) • Coverage rates and volumes for the various irrigation methods that may be employed within the field (Growers and irrigation equipment providers) • Water use and uptake properties of the various crops that will be grown in the application field (Land Grant University, Agrimanagement documentation, and other publications) • Irrigation water order and delivery information (Irrigation district and growers) • Rainfall information (measured in the field) • Crop water use and evapotranspiration estimates (Outlook, WA – AgWeatherNet weather station) • Soil bulk density (samples collected prior to sensor placement) • Soil field capacity (samples collected prior to sensor placement) *Determination of Action Level:* • The action level will be based on the volumetric water content (VWC) measured at 3 feet below ground surface. VWC will be compared with the location's soil field capacity (FC) on a volume and weight basis, respectively. VWC greater than the FC indicates conditions near saturation level of the soil beyond its water holding capacity and the potential for migration of irrigation water below the root zone. *Appropriate Sampling and Analysis Methods:* • Soil Bulk Density – Soil bulk density is a common soil measurement. The collection and analysis of soil bulk density samples will be conducted in accordance with ASTM D 2937-10.

	• Soil Field Capacity – Soil field capacity is a commonly measured soil parameter within the agricultural industry. Industry methods to determine the field capacity will be used to prepare and collect field capacity samples. Moisture content associated with the field capacity samples will be analyzed using ASTM D 2216-10. • Volumetric Water Content – Volumetric water content is a common parameter measured in agricultural settings, particularly in irrigated fields. Capacitance sensors are commonly used to measure volumetric water content in agricultural soils. • Applied Water Measurements – Input volumes can readily be measured using flow meters and/or totalizers and calculations based on pump size and electricity use on irrigation application equipment. Field application will be calculated based on the type of application equipment (sprinkler and nozzle size, etc) and by use of tipping rain gauges collocated with VWC sensors within the field. The tipping rain gauges will record both irrigation water as well as any additional water in the form of precipitation that is applied to the field. Manual rain gauges will also be located within the fields to provide verification of tipping rain gauge measurements. In the event that there are concerns regarding the uniformity of irrigation water application across the field, uniformity will be checked using a rain gauge grid evaluation within the field during irrigation.
Step 4: Define the Boundaries of the Study	*Target Population:* • The target population for the IWMP monitoring program is irrigation water within the soil column at 3 feet below ground surface in irrigated fields. The target population includes all electronic sensors that will be deployed at three feet below ground surface to adequately characterize the various field conditions and irrigation practices that are occurring within an irrigation application field. Additional electronic sensors will be deployed in the field to assist in developing appropriate irrigation water application rates and to provide information to the professional irrigation consultant regarding soil moisture conditions within the root zone. While it is anticipated that these sensors will provide valuable information regarding soil moisture conditions, only data from the 3-foot interval will be used to make decisions regarding the objective of the IWMP ("minimize water movement below the root zone." AOC SOW Section F.2). All sensor data collected as part of the IWMP (1-, 2-, and 3-foot depth interval sensors) will be used to evaluate soil moisture conditions and crop water needs. The data from these sensors will be downloaded, plotted, and interpreted to determine crop water needs and application rates on a weekly basis prior to ordering delivery for the following week. The electronic data will be submitted to EPA when downloading, plotting, interpreting, and calculating water orders and application rates are completed each week. Data submitted to EPA will be in raw format, plotted, and will include any appropriate calculations used for ordering water or changing application rates.

	Spatial Boundaries: • Horizontal – The irrigated area of the application field • Vertical – Soil moisture at 3 feet below ground surface (below the crop root zone). • Temporal – IWMP monitoring will occur during the irrigation season within fields that are being actively irrigated. *Practical Constraints on Data Collection:* • Irrigation Water Delivery – The ability to trigger immediate, automated irrigation system shutdown in the event that VWC exceeds FC is limited by the irrigation water delivery system used by the irrigation district. Based on conversations with the irrigation district Water Master, automated shutdown of individual irrigation systems within the main system could result in overflows within the system that could result in significant damage to irrigation laterals and potentially the larger canal system. The Water Master indicated that the irrigation district would not allow the use of automated shutoffs for irrigation systems receiving water from the canals. The general process for irrigation water orders from the irrigation district is initiated weekly as follows: – Growers work with their agricultural irrigation consultant to determine the amount of water that will be required for the week. – Growers place an order requesting a certain amount of water to be delivered for a certain amount of time (this is a points systems where you can request a certain rate of water in cubic feet per second or gallons per minute) – When the order is made, the Water Master directs it to the Ditch Riders who fulfill the order by metering a certain amount of water through gates and valves to the appropriate canals and laterals. – Once the request for the order is made, the grower is obligated to take the amount of water ordered. – Some changes to the order can be made during the week, but take an unspecified amount of time to make and can only be accomplished during normal working hours. Based on the restrictions on water delivery and ordering, soil moisture monitoring data will be evaluated on a weekly basis to coincide with water delivery and ordering systems developed by the irrigation district. Changes to irrigation methods and application rates will occur on a weekly basis.
Step 5: Develop a Decision Rule	*Population Parameter of Interest:* • The primary parameter of interest (saturated conditions in soil at 3 feet below ground surface) will be determined using electronic sensors placed in representative areas within the irrigated fields. Soil moisture data from the 3-foot depth interval sensors will be used to evaluate the overall objective of the IWMP ("minimize water movement below the root zone." AOC SOW Section F.2). It is anticipated that effective implementation of the IWMP and careful

	application of irrigation water to fields to maximize crop yield and minimize excess water application will result in minimizing the potential for irrigation water to move below the root zone during the irrigation season. Secondarily, additional electronic sensors will be placed at select locations within the root zone at 1 and 2 feet below ground surface. These sensors will be used to evaluate root zone moisture conditions and to further increase surety that irrigation water application rates developed by the professional irrigation consultant are appropriate for crop and climatological conditions. However, these sensors will not be used to evaluate the overall objective of the IWMP soil moisture monitoring program. Given restrictions on the ability to provide immediate, automated shut off of irrigation equipment imposed by the irrigation district, irrigation schedules, water orders, and delivery amounts will be determined on a weekly basis based on the results of the previous week's soil moisture monitoring data and anticipated weather conditions. *Primary Decision Rule:* • If VWC measurements at 3 feet below ground surface for the prior week are less than the soil field capacity, then a water order from the irrigation district will be made in accordance with the professional irrigation consultant's recommendations. • If VWC measurements at 3 feet below ground surface for the prior week are greater than the soil field capacity, then the dairy will implement changes to irrigation application including changes to irrigation application rates, reduction in the water order, changes to irrigation methods, or other changes that will result in VWC at or less than the soil field capacity.
Step 6: Specify Tolerable Limits on Decision Errors	The IWMP soil moisture monitoring program is designed to provide sufficient coverage of soil moisture conditions at 3 feet below ground surface within representative areas of the application field. Representative areas will be determined based on NRCS soil types and their measured properties within the field; topographic relief of the field; the presence of low-lying areas, swales, or drainages; and the irrigation method used for the field. The soil moisture monitoring program focuses on those areas within the field that may be the most susceptible to the migration of irrigation water below the crop root zone (such as low-lying areas within soils with the greatest permeability). Decision errors associated with the soil moisture monitoring program could result in the following: • Migration of irrigation water below the root zone (failure to detect over-application) In order to minimize the potential impact associated with decision error, the soil moisture monitoring program focuses on the placement of monitoring points within areas that would be most susceptible to the migration of irrigation water, as noted above.

Step 7: Develop the Plan for Obtaining Data	*Sampling Area Definition:* The seven irrigated fields at the Dairy are shown together on Figures 2A (aerial photograph base) and 2B (USGS 7.5-minute quadrangle base) and individually on Figures 3 through 9. A summary of the field conditions and soil types based on information provided by the Natural Resources Conservation Service Web Soil Survey is presented in Table 1. The information in Table 1 was used as the basis for data collection planning and monitoring design discussed later in this IWMP. There are five different soil types present in the irrigated fields located at the Dairy based on review of the *Soil Survey of Yakima County Area Washington* (USDA Soil Conservation Service, 1985) the Natural Resources Conservation Service Web Soil Survey. The soil types present include: • Esquatzel Silt Loam – USCS classification: ML. Very deep, well-drained soils on flood plains, formed in silty alluvium. Moderate permeability. High available water capacity. • Finley Silt Loam – USCS classification: ML/SM (shallow), increasing sand and gravel with depth. Very deep, well-drained soils on terraces and alluvial fans, formed in old alluvium. Moderately rapid permeability. Moderate available water capacity. • Scoon Silt Loam – USCS classification: ML, SM, GM. Shallow (typically less than 16 inches to hardpan), well-drained soils on uplands, formed in loess overlying hardpan. Permeability is moderate above the hardpan and very slow through the hardpan. Low available water capacity. • Shano Silt Loam – USCS classification: ML. Very deep, well-drained soils on uplands formed in loess. Moderate permeability. High available water capacity. • Warden Silt Loam – USCS classification: ML. Very deep, well-drained soils, formed in lacustrine sediment with a mantle of loess. Moderate permeability. High available water capacity. Figures 3 through 9 show the seven irrigated fields that are part of the IWMP. The approximate locations of the various soil types present in each field are shown on the figures. It should be noted, that the soil boundaries presented in Figures 3 through 9 are approximate as they were taken from the larger scale soil survey for the region. Where necessary, inferences regarding the location of the various soil types were made based on experience with the fields, geomorphic controls, and the presence of the various soil types within the fields. Therefore, in the individual field descriptions below, the location of topographic features and the soil type associated with the feature may not reflect the exact locations shown on the figures.

	A brief summary description of the soil types and topography of each of the seven irrigated fields located at the Dairy is provided below: • CP-SU-1 (Figure 3, soil type boundaries are slightly offset): Located to the south of the Cow Palace Dairy and west of Arms Road. The field is approximately 69 acres and is irrigated using a linear irrigation system. Soil types present include: – Warden silt loam – Scoon silt loam – Shano silt loam – Finley silt loam The general slope of the field is to the south. A "Y"-shaped topographic depression is present in the field in the eastern portion of the field with one branch of the "Y" extending to the northwest and the other oriented north-south. Soil types within the low lying area are predominantly the Finley and Shano silt loam units with Scoon silt loam in the northwest portion of the "Y". • CP-SU-2 (Figure 4): Located at the northwest intersection of Kirks and Arms Roads south of Field CP-SU-1. The field is approximately 72 acres and is irrigated using a combination of linear and wheel line irrigation systems. Soil types present include: – Scoon silt loam (Limited to the northwest corner of the field) – Warden silt loam The general slope of the field is to the south. A topographic depression continuing from the field to the north is present in the field and is oriented roughly north-south. The depression exits the field to the southwest to an irrigation frost pond. • CP-SU-3 (Figure 5): Located south of Zillah Road between Arms and Dekker Roads. The field is approximately 155 acres and is irrigated using a center pivot irrigation system. Soil types present include: – Finley silt loam (minor area near northwest corner of field) – Warden silt loam The general slope of the field is to the southwest. A topographic depression is present in the western portion of the field trending northeast to northwest. The soil type associated with the swale is the Warden silt loam. • CP-SU-4A (Figure 6): Located south of CP-SU-3 to the west of Dekker Road. The field is approximately 71 acres and is currently irrigated using a wheel line irrigation system. Historically, rill irrigation has was in this field when it was planted in corn. However, this practice is discontinued. The only soil type present in the field is the Warden silt loam. The general slope of the field is to the southwest. A topographic depression is present in the field trending from approximately the northeast corner to the southwest corner of the field. A frost pond is present along the depression in the southern third of the field.

- CP-SU-4B (Figure 7): Located south of CP-SU-4A to the west of Dekker Road. The field is approximately 40 acres and is currently irrigated using a wheel line irrigation system. The only soil type present in the field is the Warden silt loam. The general slope of the field is to the southwest. A topographic depression trending roughly north-south is present near the middle of the field.
- CP-SU-5 (Figure 8): Located on the northeast corner of Zillah and Arms Roads. The field is approximately 37 acres and is currently irrigated using a wheel line irrigation system. The only soil type present in the field is the Warden silt loam. The general slope of the field is to the south. A topographic depression is present in the field extending from the northeast corner of the field to the center of the southern boundary of the field.
- CP-SU-6 (Figure 9): Located on the north side of Knowles Road between Arms and Dekker Roads. The field is approximately 85 acres and is irrigated using a wheel line system. Currently, the field is planted in corn silage and irrigated using a rill irrigation system. This practice will be discontinued following the 2013 irrigation season. Soils present in the field include:
  - Esquatzel silt loam
  - Warden silt loam

  The general slope of the field is to the south-southwest. In the eastern portion of the field, a topographic depression extends from the northeast corner to the center of the southern boundary of the field. This eastern depression is located in both Warden silt loam and Esquatzel silt loam soils. A second topographic depression extends from the farthest north point of the field to the southwest corner of the field. This western depression is located in the Warden silt loam soil type.

Sampling Design:
A judgmental sampling design was used to identify the number and location of sensors that will be placed and monitored in each of the irrigated fields. The sensor placement focuses on those areas of the field that may be the most susceptible to the migration of irrigation water below the crop root zone (such as low-lying areas within soils with the greatest permeability).

The number of sensors identified for placement in the field is based on the location and type of susceptible areas as well as the irrigation methods being employed. The number and proposed locations of sensors for each field are presented in Figures 3 through 9 and are summarized below.

- CP-SU-1 (Figure 3): A total of 3 sensors will be placed in CP-SU-1.
  - Near the northeast corner of the field in the depression (Warden silt loam)
  - In the southern portion of the depression (Finley silt loam)
  - In the southwest corner of the field (Warden silt loam)
  - No sensor was identified for placement in the northwest-southeast trending arm of the depression as this area is comprised of Scoon silt loam which only extends 16 inches before hard pan.

	• CP-SU-2 (Figure 4): Two sensors will be placed in CP-SU-2.
	  – In the southern portion of the depression (Warden silt loam)
	  – Near the northwest corner of the field (Warden silt loam)
	• CP-SU-3 (Figure 5): Three sensors will be placed in CP-SU-3. Only one soil type is present over the majority of the field (Warden silt loam). The sensors will be placed in near the beginning, middle, and end of the radius of center pivot irrigation system. The middle and end sensors will be placed in the north-south trending depression.
	• CP-SU-4A (Figure 6): Two sensors will be placed in CP-SU-4A. Only one soil type is present in CP-SU-4A (Warden silt loam). The sensors will be placed near the southern end of the northeast-southwest trending depression below the frost pond and in the center of the western portion of the field.
	• CP-SU-4B (Figure 7): Two sensors will be placed in CP-SU-4B. Only one soil type is present in the field (Warden silt loam). One sensor will be placed along the northern portion of the north-south trending depression and the other will be placed in the northwest quadrant of the field.
	• CP-SU-5 (Figure 8): Two sensors will be placed in CP-SU-5. Only one soil type is present in the field (Warden silt loam). One sensor will be placed in the north-south trending depression. The other will be placed in the southwest quadrant of the field.
	• CP-SU-6 (Figure 9): Three sensors will be placed in CP-SU-6.
	  – In the northern portion of the field in the western depression (Warden silt loam)
	  – In the middle of the field (Warden silt loam)
	  – In the eastern depression (Esquatzel silt loam)
	
	All sensors in all fields will be set to record the volumetric water content on an hourly basis. Sensor information will be recorded on a data logger and will be downloaded on a weekly basis. The data will be downloaded and analyzed prior to placement of the weekly water order with the irrigation district.
	
	The professional irrigation consultant will determine the number of inches of irrigation water on a per acre basis for each field. The Dairy will work with the irrigation district Water Master to determine the volume and delivery rate of water for the week.

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Appendix B

Field Forms

AGRIMANAGEMENT® INC.
AGRICULTURAL CONSULTANTS

Irrigation Sampling Input Sheet

Client: H385 Matson Fruit Company - Mattawa
Field: Block 1543 - 2008 Gravimetric

JobNum: 3735
Region: M
Report Num: I13-_____

Crop: (TAPPL) - Apples - Cripps Pink
Acres: 21
Irr: Sprinklers

Last Sampled: 9/30/2013 Hanson
Anticipated Recheck Date: None
Average Sampling Depth (ASD): 3.0

Sampling Instructions
Sample ***Inside / Outside*** **Sample Strip**
Sample_____A,B_____C,D OR _____Foot Increments to _____Feet
Comments:_____

Field Bio:
Pink Lady 08
SS - Rows 47-52
UT 9x36. OT 36x45.
Tree spacing 4x8' 8 wire VH
0.4 GPH @ 2' spacing
in/ac - total = 0.036"/hr

Sampler's Report

Set up Charge: Billed

Sample Date: _____ ***Sampler:*** _____

Crop Vigor: Poor / Fair / Good / Exc

Crop Stage: [ ][ ][ ] _____ Last: (016) - Post-Harvest

Crop Color: [ ][ ] Last: (04) - Normal Green

Cover Crop/Weeds, other: _____

Comments related to Irr Pattern: _____

Sampler Comments: _____

Sampled Inside Sample Strip? Y / N **In Irrigation? OFF/ ISS/ OSS** **Irr Cycle: [ ][ ]:[ ][ ]**

Sampled along (wetter/drier) portion of (rows/middles) **Estimated _____(Sets/ Days) (before/after) Irrigation**

Previous Data:		% AW	Est	FC
Sample Strip	1	64%	65%	15.5
Sample Strip	2	85%	78%	18.0
Sample Strip	3	108%	82%	19.0

Anticipated Next Sampling Date:

Sample Area	Depth	Can#	Est. %AW	Wet wt.	Dry wt.	Sample Area	Depth	Can#	Est. %AW	Wet wt.	Dry wt.

Rain Gauge Readings: _____ _____ _____ _____

ERD Overide: 3.0
DCU Overide:

ARCADIS

Appendix C

Decagon EC-5 Manual

EC-5

Soil Moisture Sensor

User's Manual

Version 2

DECAGON DEVICES

Decagon Devices, Inc.
2365 NE Hopkins Court
Pullman WA 99163 USA
(509) 332-5600

Contents

1. Introduction

EC-5 Specifications

Measurement Time: 10ms (milliseconds)

Accuracy: at least 0.03 m^3/m^3 all soils, up to 8 dS/m
With soil-specific calibration: ±.02 m^3/m^3 (±2%)

Resolution: 0.001 m^3/m^3 VWC in mineral soils, 0.25% in growing media

Power Requirements: 2.5VDC - 3.6VDC @ 10mA

Output: 10-40% of excitation voltage (250-1000mV at 2500mV excitation)

Operating Environment: -40 to +60 °C

Range of Measurement: 0 to saturation

Sensor dimensions: 8.9cm x 1.8cm x 0.7cm

Cable length: 5m standard, custom lengths or extension cables are available

Connector types: 3.5 mm plug or stripped and tinned lead wires

Data Logger Compatibility (not exclusive):
Decagon: Em5b, Em50 series loggers
Campbell Scientific: CR10X, 21X, 23X, CR1000, CR3000, etc.

Customer Support

If you ever need assistance with your EC-5, or if you just have questions or feedback, there are several ways to contact us. Customer service representatives are available to speak with you Monday thru Friday, between 7am and 5pm Pacific time.

***NOTE**: If you purchased your EC-5 through a distributor, please contact them for assistance.*

E-mail:
support@decagon.com or sales@decagon.com

Phone:
1-509-332-5600

Fax:
1-509-332-5158

If contacting us by email or fax, please include as part of your message your name, address, phone, and fax number along with a description of your problem.

Warranty Information

The EC-5 has a 30-day satisfaction guarantee and a one-year warranty.

Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from date of receipt of equipment (the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause are not to be considered a defect); but Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts F.O.B. the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

2. About the EC-5

The two-prong design and higher measurement frequency allows the EC-5 to measure VWC from 0 to 100% (VWC of saturated soils is generally 40-60% depending on the soil type) and allows accurate measurement of all soils and soilless medias with a wide range of salinities.

Sensor Features

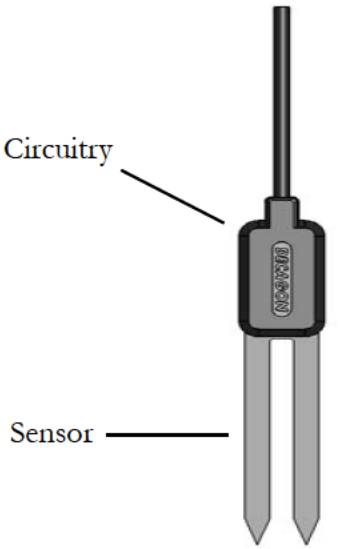


Fig. 1: EC-5 diagram

Wiring Diagrams

3.5mm Plug Wiring

The EC-5 comes with a 3.5mm "stereo plug" connector. This allows for rapid connection directly to Decagon's Em50 and Em5 loggers and the ProCheck. Below is a diagram showing the wiring configuration for this connector.

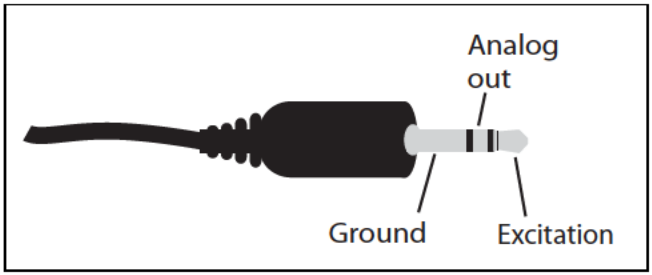


Fig. 2: 3.5mm "Stereo Plug" wiring configuration

Wiring to Non-Decagon Data Loggers

Models with stripped and tinned leads are pre-configured for connecting to non-Decagon data loggers. Simply wire the lead into the data logger as described in "Connecting to a Data Logger" in Chapter 4.

If your model uses the standard 3.5mm plug, you have two choices when attaching the sensor to non-Decagon data loggers. First, you can clip off the plug on the sensor cable, strip and tin the wires, and wire it directly into the data logger. This has the advantage of creating a direct connection with no chance of the sensor becoming un-plugged; however, it then cannot be used in the future with a Decagon Em50 or Em5 logger. The other

choice is to obtain an adapter cable from Decagon. The 3-wire sensor adapter cable has a connector for the sensor jack on one end, and three wires on the other end for connection to a data logger (this type of wire is often referred to as a "pigtail" adapter). Both the sensor wire and adapter cable wire have the same wire output (shown in Fig. 3); the white wire is excitation, red is output, and the bare wire is ground.

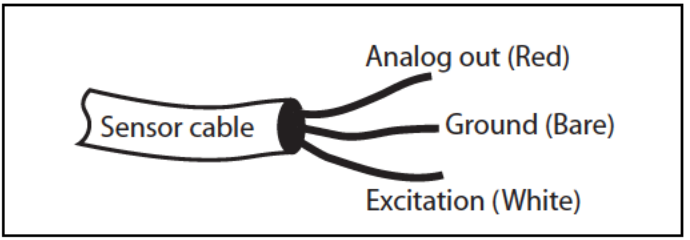


Fig. 3: 3-wire cable wiring configuration

Extended cable lengths

Decagon recommends that you purchase customized cable lengths if your project requires longer cable leads. Custom cable lengths may be requested with a 3.5mm connector or stripped & tinned end.

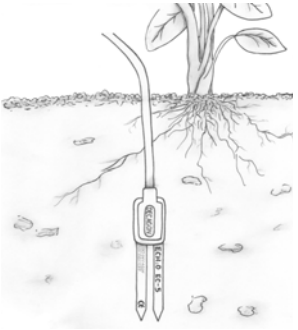
3. Installing the Sensors

When selecting a site for installation, it is important to remember that the soil adjacent to the sensor surface has the strongest influence on the sensor reading and that the sensor measures the *volumetric* water content. Therefore any air gaps or excessive soil compaction around the sensor can profoundly influence the readings. Also, do not install the sensors adjacent to large metal objects such as metal poles or stakes. This can attenuate the sensor's electromagnetic field and adversely affect output readings. Because the EC-5 has gaps between its prongs, it is also important to consider the size of the media you are inserting the sensor into. It is possible to get sticks, bark, roots or other material stuck between the sensor prongs, which will adversely affect readings. Finally, be careful when inserting the sensors into dense soil, as the prongs will break if excessive sideways force is used when pushing them in.

Procedure

When installing the EC-5, it is best to maximize contact between the sensor and the soil.

1. The EC-5 sensor was designed for easy installation into the soil. After digging a hole to the desired depth, push the prongs on the sensor into undisturbed soil at the bottom of the hole or into the sidewall of the hole. Make sure that the prongs and black overmolding are buried completely as shown below.



The sensor may be difficult to insert into extremely compact or dry soil. If you have difficulty inserting the sensor, try loosening the soil somewhat or wetting the soil. ***Never pound it in!***

2. Carefully backfill the hole to match the bulk density of the surrounding soil. Be careful not to bend the black overmolding connecting the sensor to the cable.

To watch a video on proper installation of the sensor go to www.decagon.com/install.

Orientation

The sensor can be oriented in any direction. However, orienting the flat side perpendicular to the surface of the soil will minimize effects on downward water movement.

Removing the Sensor

When removing the sensor from the soil, ***do not pull it out of the soil by the cable!*** Doing so may break internal connections and make the sensor unusable.

4. Collecting Data

Data Logger Requirements

The EC-5 sensor is designed to work most efficiently with Decagon's 5-channel Em5b, Em50, or ProCheck handheld readout. All Decagon readout devices use a 3.0V excitation.

The sensors however, may be adapted for use with other data loggers, such as those from Campbell Scientific, Inc., for example. The EC-5 requires an excitation voltage in the range of 2 to 3.6 volts. The sensors produce an output voltage that depends on the dielectric constant of the medium surrounding the sensor, and ranges between 10 and 50% of the excitation voltage. Any data logger which can produce a 2.5 to 3.6V excitation with approximately 10 millisecond duration and read a volt-level signal with 12-bit or better resolution should be compatible with the EC-5 sensor. The current requirement for the EC-5 is 10mA at 2.5V.

NOTE: *EC-5 sensors are intended only for use with data loggers and readout devices which can provide short excitation pulses, leaving the sensors turned off most of the time. Continuous excitation not only wastes battery power, but may, under certain circumstances, cause the sensor to exceed government specified limits on electromagnetic emissions. Do not continuously power the EC-5 sensor.*

Connecting to a Data Logger

Connect the wires to the data logger as shown, with the supply wire (white) connected to the excitation, the analog out wire (red) to an analog input, and the bare ground wire to ground:

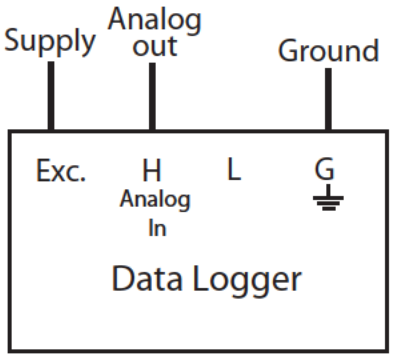


Fig. 5: Data logger configuration

Sample Program

The following program is an example that can be used with Campbell Scientific's CR10X data logger and our EC-5 sensor at a 2500mV excitation:

```
;{CR10X}
;   Example ECH2O Data Logger Program for CR10X

;   Wiring:

;   White: Excitation Channel 1
;   Red: Input Single Ended Channel 1
;   Black: Ground

*Table 1 Program
```

```
  01: 1        Execution Interval (seconds)

;  Factory calibration equations for ECH2O
;  probes convert mV output of ECH2O to
;  volumetric water content (VWC, m3/m3)

;  EC-5:   VWC = 0.00119 * mV - 0.400

1:  Excite-Delay (SE) (P4)
 1: 1        Reps
 2: 5        2500 mV Slow Range
 3: 1        SE Channel
 4: 1        Excite all reps w/Exchan 1
 5: 1        Delay (0.01 sec units)
 6: 2500     mV Excitation
 7: 1        Loc [ Probe_VWC ]
 8: .00119   Multiplier
 9: -.4      Offset

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

SCWin (Short Cut) Directions

The following are instructions for using Campbell Scientific's SCWin (Short Cut) program to read the EC-5 soil moisture sensor.

1. Download EchoCSI.zip from http://www.decagon.com/appnotes/EchoCSIappnote.pdf.
2. Unzip the folder EchoCSI.zip.
3. Locate the file containing SCWin.exe. It should be in C:\Program Files\Campbellsci\SCWin. Place the

following files from the unzipped EchoCSI.zip folder into the folder with SCWin.exe:

AM1632Z.MUX
AM416Z.MUX
EC10.SCS
EC101632.SCS
EC10416.SCS
EC20.SCS
EC201632.SCS
EC20416.SCS
EC5.SCS
EC5632.SCS
EC5416.SCS
SCWIN-DECAGON.CNT
SCWIN-DECAGON.HLP

Note: *If you are not able to find this directory path, search for the folder that contains SCWIN.exe and place the files into that folder.*

4. Open up SCWin.exe (Short Cut). If you are using a V.3 copy of LoggerNet, there is a tab for SCWin (Short Cut) on the tool bar.

5. Select "New" to start a new program to read the EC-5.
   a. Select the data logger you will be using to read the sensors.
   b. Select the measurement interval (a shorter measurement interval, i.e. 1 sec., is sometimes desirable when testing the sensor).

6. Click on Sensors (this should open a new page with a file tree on it).

7. Under the "Sensors" file tree, double-click on "Meteorological" and then select "Soil Moisture."
8. Choose "EC-5" Sensor.

Calibration

Decagon's ECH_2O Utility, and DataTrac3 automatically apply factory calibrations to the sensors' output data. However, this general calibration may not be applicable for all soil types. For added accuracy we encourage our customers to perform soil-specific calibrations.

The calibration equation that you will use depends on where you will be using it. If you will be using it with sensors connected to a non-Decagon data logger you will need to use the 2500 mV calibration. If you use any Decagon software (DataTrac3, ECH_2O Utility, etc.) or the user calibration menu in the ProCheck, you will need to use the RAW calibration. The difference between the two is the slope constant. To increase the resolution of the sensor output, Decagon uses all available increments of the 12-bit number (value of 4096) where the measurement is stored. Thus, the output of the sensors read by the ProCheck and Decagon loggers must be multiplied by 0.61 AND the 2500 mV slope to give the right value.

Sensor Calibration Values

Following is a list of the both the millivolt and RAW calibration values for the EC-5, where θ is the volumetric water content, mV is the millivolt output of the sensor, and where *x* is the RAW sensor output.

The EC-5 is much less sensitive to variation in texture and electrical conductivity because it runs at a much higher measurement frequency. Therefore, its general calibration equation should apply for all mineral soils up to 8 dS/m saturation extract. Its calibration equations are shown below for mineral soil, potting soil, and rock-wool growing media:

Dielectric Permittivity

Dielectric permittivity can be used to determine volumetric water content using external published equations such as the Topp equation. Dielectric permittivity is given by

$$\varepsilon = 1/(-1.10570 \times 10^{-9} * RAW^3 + 3.57500 \times 10^{-6} * RAW^2 - 3.95570 \times 10^{-3} * RAW + 1.53153)$$

where RAW is the output from the Decagon data logger using 3V excitation. If you are using a non-Decagon data logger, dielectric permittivity is given by

$$\varepsilon = 1/(-3.33260 \times 10^{-9} * mV^3 + 7.02180 \times 10^{-6} * mV^2 - 5.11647 \times 10^{-3} * mV + 1.30746)$$

Mineral Soils

According to our tests, a single calibration equation will generally suffice for all mineral soil types with electrical conductivities from 0.1 dS/m to 10 dS/m saturation extract. Volumetric water content (ø) is given by

$$ø = 8.5 * 10^{-4} * RAW - 0.48 \quad (1)$$

where *RAW* is the output from the Decagon data logger using 3V excitation. If you are using a non-Decagon data logger, VWC is given by

$$ø = 11.9 * 10^{-4} * mV - 0.401 \quad (2)$$

where mV is the output of the sensor when excited at 2500 mV. Please note that the equation will reach a maximum at ~60% volumetric water content (VWC) in pure water. To display data on a scale from 0 to 100%, VWC should be modeled with a quadratic equation (which would result in a 100% VWC in water), but a linear equation fits the mineral soil VWC range as well as the quadratic, and linear equations are easier to deal with, especially since mineral soil typically saturates at ~40 - 50% VWC.

Potting soil

The following equations can be used to convert EC-5 output to water content in potting soil. We tested several types of potting soil (Sunshine mix, Miracle Grow Potting Mix, and Custom Nursery soil) at several salinities and found that VWC is given by

$$ø = 1.3 * 10^{-3} * RAW - 0.696 \quad (3)$$

for a Decagon data logger or

$$ø = 2.11 * 10^{-3} * mV - 0.675 \quad (4)$$

for a data logger with 2500mV excitation.

Rockwool

The EC-5 was calibrated in Grodan Master rockwool with solution electrical conductivities of 0.2, 1.0, 1.5, 2.0, and 4.5 dS/m. Volumetric water content can be calculated using

$$ø = 6.28 * 10^{-7} * RAW^2 + 1.37 \times 10^{-4} * RAW - 0.183 \quad (5)$$

for a Decagon data logger or

$$ø = 2.63 * 10^{-6} * mV^2 + 5.07 \times 10^{-4} * mV - 0.0394 \quad (6)$$

for a data logger with 2500 mV excitation.

NOTE: *These calibration constants only apply to 2500mV excitations; use of these numbers with any other excitation voltage will result in erroneous readings***!**

Troubleshooting

If you encounter problems with the EC-5, they most likely will manifest themselves in the form of incorrect or erroneous readings. Before contacting Decagon about the sensor, do the following:

- **Check to make sure the connections to the data logger are both *correct* and *secure*.**
- **Ensure that your data logger's batteries are not dead or weakened.**

If you encounter problems that aren't due to the data logger, please contact Decagon at **(509) 332-5600** or at **support@decagon.com**.

Declaration of Conformity

Application of Council Directive:	89/336/EE6
Standards to which conformity is declared:	EN61326 : 1998 EN51022 : 1998
Manufacturer's Name:	Decagon Devices, Inc. 2365 NE Hopkins Court Pullman, WA 99163 USA
Type of Equipment:	Soil moisture sensor
Model Number:	EC-5
Year of First Manufacture:	2001

This is to certify that the EC-5 ECH_2O soil moisture sensor, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA meets or exceeds the standards for CE compliance as per the Council Directives noted above. All instruments are built at the factory at Decagon and pertinent testing documentation is freely available for verification.

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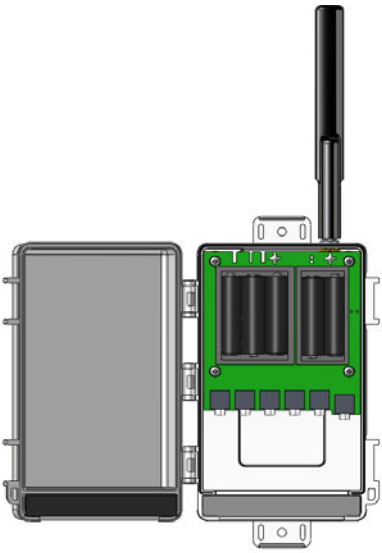
Appendix D

Decagon Em50 Manual

Em50/Em50R/Em50G

Em50 Series Data Collection System

User's Manual



Version 12

DECAGON DEVICES

Decagon Devices, Inc.
2365 NE Hopkins Court
Pullman, WA 99163 USA

Contents

1. Introduction

Thank you for choosing the Em50 data logger series. These data loggers are designed and suited for field research and commercial agriculture. This manual will explain the Em50's capabilities and functions.

NOTE*: Except where specified, all functions and specifications relating to the Em50 also relate to the Em50R and the Em50G.*

Customer Support

If you ever need assistance with your Em50, or if you just have questions or feedback, there are several ways to contact us Customer Service Representatives are available to speak with you Monday thru Friday, between 7am and 5pm Pacific time.

NOTE*: If you purchased your Em50 through a distributor, please contact them for assistance.*

E-mail:
support@decagon.com or **sales@decagon.com**

Phone:
1-509-332-5600

Fax:
1-509-332-5158

If contacting us by email or fax, please include as part of your message your instrument's serial number, your name, address, phone, and fax number.

You can also send feedback to Decagon using ECH_2O Utility's "Send Feedback to Decagon" feature. See Appendix B for more information.

Specifications

Input Ports: 5, 12-bit analog or 32-bit digital

Port type: 3.5mm "stereo jack" connector

Data Storage: 1MB (36,800 scans for all 5 ports)

Memory type: Non-Volatile Flash

Battery capacity:5 AA Alkaline or Lithium batteries

Enclosure: Weatherproof, impact and UV-resistant polymer

Enclosure rating: IP55, NEMA3R

Operating environment: 60° to -40°C, up to 100% RH

Communication: Dedicated serial port 3.5mm stereo jack for use with the Decagon USB Cable Adapter (UCA).

Radio (Em50R models):

902 - 928 MHz ISM *North America*
915 - 928 MHz ISM *Australia, New Zealand, Israel*
2.4 GHz ISM *Worldwide*

Cellular (Em50G): *GSM/GPRS Cellular technology. Cellular service and data hosting service provided by Decagon Devices.*

Software Downloads and Updates

Go to www.Decagon.com/support/downloads if you need to download firmware updates, software updates and/or drivers.

Warranty

All Decagon products have a 30-day satisfaction guarantee and the Em50 has a one-year warranty.

Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from date of receipt of equipment (the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause are not to be considered a defect); but Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts F.O.B. the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

2. Em50/Em50R/Em50G

Em50 Logger Series Overview

Introduction

The ECH_2O System is made of data loggers, sensors, telemetry, and software that help you measure soil moisture and other environmental parameters accurately and cost effectively. Decagon's innovative sensors are the heart of the system. Decagon also designed the system to be very easy to use (no programming needed).

About the Em50 Logger Series. The Em50 is a 5-port, self-contained data logger especially suited for field research and commercial agriculture. The Em50 logger series includes three models: the Em50, the Em50R and the Em50G. These devices are housed in a weather-resistant enclosure, making them suitable for long-term outdoor operation.

Em50

The Em50 is the basic logger. The communication with this model is through a stereo to USB or stereo to Serial cable to a PC or mobile handheld device.

Em50R

The Em50R includes a spread-spectrum radio telemetry module. The radio module is available in long-range 900 MHz and 2.4 GHz frequencies. Use the telemetry in energy efficient transmit mode or two-way mode. (See Chapter 6 for more information on telemetry.)

Em50G

The Em50G includes a GSM/GPRS (Global System for Mobile communications/General Packet Radio Service) cellular module to allow environmental measurement data available over the internet. Decagon partners with a provider of global cellular data service to make data transmission and maintenance easy and inexpensive. Measurements from the Em50G are sent wirelessly to Decagon's internet server and are available for download using DataTrac 3 software or the Em50G WebViewer.

Em50 Compatible Sensors

You can use the Em50 to log data for almost all of the sensors that Decagon sells (excluding the UMS and thermal sensors). Please see our website (www.decagon.com) or our catalog for an up-to-date list of supported sensors.

Software

The Em50 series gives you two software options for working with your hardware and collected data. Choose one or both packages to fit your needs. Download the latest versions of these programs at **www.decagon.com/support/downloads.**

ECH_2O Utility

ECH_2O Utility is free software that is included with your purchase. It provides a simple way to connect to and configure your loggers. The ECH_2O Utility makes downloading and processing your measured data fast and easy.

- Connect to Em50 loggers directly or with radio telemetry.
- Set all logger configuration parameters with visual controls.
- Make real-time sensor measurements (scan sensors).

- Create Excel or text files with raw or processed data.
- Create configuration and data files for use with DataTrac.

DataTrac 3

DataTrac 3 is the premier Em50 series system software designed to help you organize and visualize your measurement data. DataTrac 3 transforms endless columns and rows of raw data into meaningful, easily-interpreted graphs. DataTrac 3 comes with the Em50 system as a 30-day trial version. If you would like to continue to use DataTrac 3, contact Decagon to purchase a DataTrac 3 registration code. With DataTrac 3 you can:

- Explore trends and relationships in real time.
- You can adjust date ranges, add or subtract data from specific sensors, and change target bands to illustrate and explore your findings. Powerful charting engine shows data graphically.
- Use DataTrac 3's Growing Tools to combine data streams and track meaningful indicators. For example, plot vapor pressure deficit instead of just temperature and humidity. Or track growing degree days, plant available water, pore water EC, etc.
- Use the "virtual sensor" tool to add information you wish you had. For example, you can measure precipitation on just one logger and make that data stream a "virtual sensor" on every logger at that site.
- Automatically collect data from your Em50G and Em50R loggers. All data—including manually collected data--will be automatically organized and added to your files chronologically.

- Watch your data in real time. DataTrac 3 updates automatically while it's running and every time it starts up.
- Add notes and ideas to the data stream. Comments and reminders can help you make sense of a growing season's worth of data later.
- Educate and inform your team efficiently. DataTrac 3's graphics reduce the time and expertise needed to understand soil moisture data.
- With this much data, you can spend enormous amounts of time scrolling through looking for answers. DataTrac 3 lets you explore your data graphically and discover quicker answers and unexpected insights.

ECH$_2$O Utility Mobile

ECH$_2$O Utility Mobile is designed to bring the usefulness of ECH$_2$O Utility to Windows powered mobile devices or handheld computers (PDA). Use this software and your PDA in the field instead of your expensive laptop. This software will configure your logger, download data, and make real-time sensor measurements. Like the desktop version, ECH$_2$O Utility Mobile allows you to:

- Connect directly or with radio telemetry to Em50 loggers.
- Set all logger configuration parameters with visual controls.
- Make real-time sensor measurements (scan sensors).
- Creates configuration and data files for use with DataTrac 3.
- Creates data files for use with ECH$_2$O Utility.

ECH$_2$O Utility Mobile works with most Windows PDAs, including the HP iPAQ. Decagon Recommends using the Juniper Systems Archer field PC (available from Decagon). This

ultra-rugged mobile device is designed to work in field conditions where typical PDA hardware will fail. Please see the ECH_2O Utility Mobile manual for more information on system requirements to use your PDA with the ECH_2O System.

Em50G WebViewer

The Em50G WebViewer is a free web-based application that allows you to remotely download spreadsheets and view weekly graphs of your data without a DataTrac 3 license. For more information on the Em50G WebViewer, see Chapter 4.

Em50 Series Data Logging Scheme

The Em50 will not make sensor measurements until you set a measurement interval. You also need to configure the Em50 ports with the type of sensor plugged into each port. You can set these values using the software described in the previous section.

Em50 Measurement Interval

The measurement interval controls how often data is recorded in the Em50's internal data storage. The interval you choose applies to all 5 ports on the Em50, therefore, it is not possible to have one port measuring sensors more or less frequently than another port.

The measurement interval works relative to the Em50's internal real-time, 24-hour clock. For example, when choosing a measurement interval of 120 minutes, the Em50 will store data every two hours, on the hour. The resulting data will show sensor measurements hourly at 12:00 a.m., 2:00 a.m.,..., 10:00 p.m. Choosing a measurement interval greater than 720 results in one set of data stored per day. For most applications, a measurement interval of 60 or 120 minutes is appropriate.

NOTE: *Setting the Em50 measurement interval to zero turns off sensor measurement and data storage.*

For most sensor types, the Em50 makes a measurement from each of the 5 sensor ports every 60 seconds, regardless of the measurement interval value. When the Em50's internal clock reaches the user-programmed measurement interval, the Em50 stores the average of all the 60-second sensor readings taken since the last storage interval. Therefore, if you set the measurement interval to 60, the Em50 will actually store an average of the past 60 sensor readings. If you choose an interval of 1440, the Em50 will store one value that represents the average sensor value for the entire 24-hour period.

NOTE: *The Em50G supports 5 minutes as the minimum value for the measurement interval setting.*

Data Storage Format

The Em50 stores "raw" data for each sensor. The stored values are not in millivolt units. Please review your individual sensors operators manual or visit our website (www.decagon.com) for up to date equations to convert raw data to meaningful sensor values.

How the Em50 Stores Data

The Em50 stores data for all five sensor ports for each measurement interval. If no sensor is connected to one or more of the logger's ports, the Em50 will store a "0" for that port. The Em50's data memory is non-volatile flash. Removing the batteries or performing a system reset will not erase your data. However, it will reset the clock in the data logger. To reset the clock to the correct time, simply connect your Em50 to a computer or handheld device running ECH_2O software.

Data Storage Size

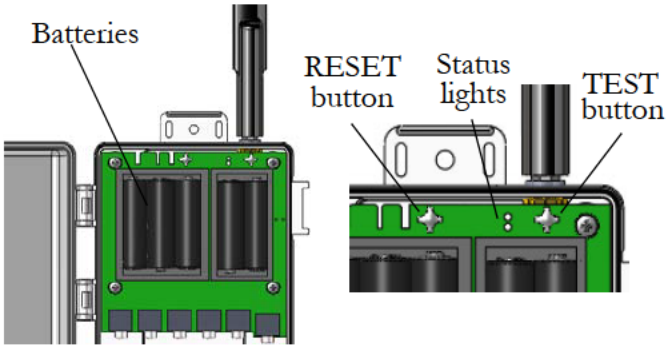
The Em50 stores more than 36,800 data scans. When the logger has filled its data memory, it begins overwriting the oldest data in the memory.

Measurement Span

Depending on the set measurement interval, the Em50 can read for several weeks to several years before its memory has filled. When you set up your Em50 using ECH_2O Utility, the software will display how many days of data the Em50 will hold based on the measurement interval that you have chosen. You can determine how many days of data your Em50 will hold by dividing the size of the data memory (36,864 scans) by the measurement interval. For example, an Em50 set on an hourly measurement interval will store 1,500 days, or about 4 years, worth of data. An Em50 set to five minutes will store data for 125 days, or about four months.

3. Setup and Installation

Installing the Batteries



The Em50s are shipped with a new set of AA alkaline batteries. Open the case and install the batteries in the proper orientation as indicated in the battery locations. After installing the batteries, press the silver Reset button located directly above the batteries.

NOTE: *Installing or changing the batteries in your Em50 resets the internal real-time clock. You must connect to your Em50 using any ECH$_2$O System software to reset the logger's clock. If you don't set the logger's clock, the time and date associated with each measurement will be incorrect.*

The Em50 is powered by 5 AA-size Alkaline batteries. With the radio or cellular modules disabled, a set of Alkaline or Lithium batteries can last for several years. The battery life for Em50Gs and Em50Rs varies depending on how the transmission is

setup. (See Chapter 6.) Battery power in the Em50R and Em50G can last from six months to over a year.

You can check the battery level status when the Em50 is connected using any ECH_2O software. When the battery life indicator shows that your Em50's batteries are less than 5%, you should replace them.

Reset Button

All Em50 logger types have a "RESET" button. If your logger doesn't respond to connection attempts or doesn't appear to be working, press the reset button. This will reboot the logger and the "STATUS" light will turn on momentarily. The internal data storage of the logger is non-volatile so you will not loose data or settings if you press the reset button.

Em50R STATUS Light

The green "STATUS" light indicates the current status of your Em50R logger.

- A short, single blink every 5 seconds indicates the Em50R is configured to log sensor data. The light doesn't blink if the logger's measurement interval is set to 0 or "Off".
- A slow on/off blink indicates the Em50R is connected to an active serial port.
- A rapid continuous blink indicates the logger's date and time are not set correctly. This can happen when the batteries have been disconnected. You must connect to your Em50R using any ECH_2O System software to reset the logger's internal clock. The logger will stop error blinking when the date is reset or after 2 minutes have elapsed (to preserve battery power).

Em50/Em50G Status Lights

The "OK" (green) and "ERROR" (red) lights indicate the current status of your Em50/Em50G logger.

- The lights indicate the status of the logger's self test function (see below).
- A short, single blink of the "OK" (green) light every 5 seconds indicates the Em50/Em50G is configured to log sensor data. The light doesn't blink if the logger's measurement interval is set to 0 or "Off".
- The "OK" (green) light blinks slowly on/off blink indicates the logger is connected to an active serial port or the cellular module is powered on.
- The "OK" (green) light pulses when the Em50G is actively sending data over the cellular network.
- The "ERROR" (red) light blinks continuously to indicate the logger's date and time are not set correctly. This can happen when the batteries have been disconnected. You must connect to your Em50/Em50G using any ECH_2O System software to reset the logger's internal clock. The logger will stop error blinking when the date is reset or after 2 minutes have elapsed (to preserve battery power). Pressing the "TEST" button may also reset the loggers clock by using the time of the cellular network if the connected network supports time information.

Em50/Em50G TEST Button

The Em50/Em50G logger has a TEST button to perform basic functionality testing. When you press the TEST button, the logger performs several checks on internal systems and attempts a communication session over the cellular network, if

an Em50G. The logger uses the status lights during the test as follows:

- Both the "OK" (green) and "ERROR" (red) lights blink slowly while the Em50G is performing the tests. Please be patient. It can take as much as 60 seconds or more to finish the cellular communication tests in the Em50G.
- The "OK" (green) light pulses when the Em50G is actively sending data over the cellular network.
- A solid "OK" (green) light indicates the internal tests passed and there was successful communication over the cellular network to the Decagon Data Service. The Em50G leaves the light on for approximately 20 seconds.
- A solid "ERROR" (red) light indicates an error in the logger or in communicating to the Decagon Data Service. Please use the Communication Test feature in ECH_2O Utility to find the specific error.

Installing Software

The ECH_2O Utility and DataTrac 3 software (installation cd is attached to the cover of this manual) allows you to collect and manage data from your device.

NOTE: *This manual documents ECH_2O Utility. Most tasks that can be performed using the ECH_2O Utility can also be accomplished using DataTrac 3 or ECH_2O Utility Mobile. For more information about using DataTrac 3 or ECH_2O Utility Mobile, please refer to their respective manuals.*

To install ECH_2O Utility, DataTrac 3, or Em50G software, place the CD in your CD drive, and wait for it to auto-launch. If it doesn't launch, go to My Computer, select your CD drive,

and click on the "setup.exe" file. A driver for the accompanying USB cable can also be installed at this time.

Occasionally, new versions of ECH_2O System software will become available on Decagon's website. They can be accessed at **www.decagon.com/support/downloads.**

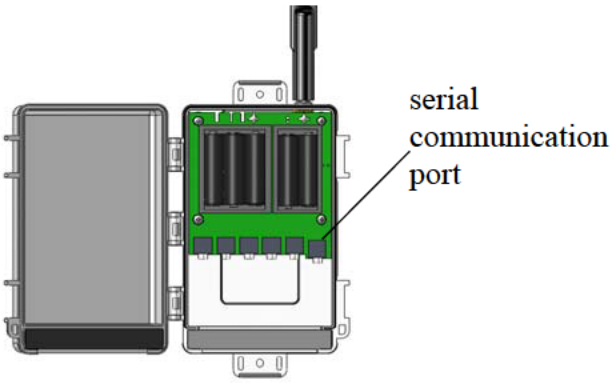
You can find your current software version in the "About" option of the Help menu in the ECH_2O Utility and DataTrac 3. If you are connected to the internet, select "Check for Updates" in the Help menu to see if there is a newer version available.

Decagon USB Cable Adapter (UCA) Driver Installation
You must install a driver for the USB Cable Adapter (UCA) before you can use it to communicate with your logger. You can find the driver installer on your ECH_2O System Software CD or from Decagon's website at www.decagon.com/support/downloads.

Configuring in ECH_2O Utility

Before field installation, the Em50 needs to have certain parameters set, such as name, date and time, measurement interval, and communication mode. Also, the radio-enabled Em50R and the cellular Em50G will not respond to wireless contact until properly configured to do so. To configure the logger, do the following:

1. Open the ECH_2O Utility program.
2. Plug the 3.5 mm connector of the UBS cable (included with your Em50) into the logger's COM port, and plug the USB into the serial port of your computer.



Port diagram

3. At the top of the screen, select the appropriate COM port from the "Connect Via" drop-down menu, then click on the "Connect" icon. If you are using the USB Cable Adapter, look for the "Connect Via" option that includes "Decagon UCA" in the COM port name.

NOTE: *If you cannot connect to your Em50, you may need to install the driver for the USB cable. To download a driver go to www.decagon.com/support/downloads.*

4. Once you have successfully connected, the menus on the main screen will become active.

5. At the device setup screen that appears, click on the various fields to enter a name for your logger and choose sensor types for each port.

   When using the Em50R, select the radio settings you plan to use (See Chapter 6). Click on "Apply" to save the changes. When using the EM50G, select your communication configurations (see Chapter 4: Software and Configuration).

6. Press the "Disconnect" icon when finished.

Field Installation

NOTE: *To watch a five minute video on installation, visit www.decagon.com/videos.*

The Em50 will serve as a collection station for up to 5 sensors. The Em50 is compatible only with sensors made by Decagon such as the ECH_2O water content probes, rain gauge, temperature sensors, etc. To install the Em50 and sensors, do the following:

1. If you are using the Em50R or Em50G, perform a telemetry test to check the wireless signal. If your signal is low or does not exist, move to an alternative location. (Sometimes only a few feet away will be sufficient.)
2. Install your sensors as directed in the respective sensor's manual.
3. Plug the sensor's jack firmly into the Em50 input port.
4. On the top and bottom of the Em50, there are two loop-holes. Use these to fasten the Em50 to a mounting post using the included zip-ties or a similar fastener. Make sure it is installed in an upright position, with the 5 input ports underneath. In this position, rain and spray are shed by the enclosure and drip off without affecting the contents of the Em50 enclosure.
5. Configure the Em50 using ECH_2O Utility, ECH_2O Utility Mobile, or DataTrac 3.

Cautions

When you install an Em50 series logger, remember:

- Do not immerse the Em50 in liquids.

- Make sure to install the Em50 upright to reduce the possibility of water entering the Em50 enclosure.
- Do not install Em50R or Em50G wireless loggers near large metallic objects, as these can attenuate the radio signal.

If the Em50R or Em50G is mounted to a metallic post, be sure to use an antenna extension cable to mount the antenna to the top of the post. This will maximize the transmit range of the Em50 wireless transmission.

4. Software & Configuration

The Em50 series data loggers were designed to have simple configuration and no data logger programming. The software packages below were designed to fit a variety of users.

- **ECH_2O Utility**--Use ECH_2O Utility for basic data logger configuration and direct connect data download in Excel format. For users with a windows laptop, netbook, or desktop computers.

  **ECH_2O Utility cannot download Em50G data from Decagon Data Service.*

- **DataTrac 3**--Use DataTrac 3 for configuring and organizing multiple Em50 series loggers. DataTrac 3's database system automatically updates newly downloaded data and creates graphs of complete data sets from each logger. DataTrac 3 is the premier software for downloading and collecting data from Em50R or Em50G systems. This software is best if you are interested in viewing your data on a daily or weekly basis because of the software's ability to automatically append new data collected by each logger.

- **ECH_2O Utility Mobile**--Use ECH_2O Utility Mobile to configure and download data on Em50 data loggers when using a handheld device such as an Archer or iPAQ running Windows Mobile.

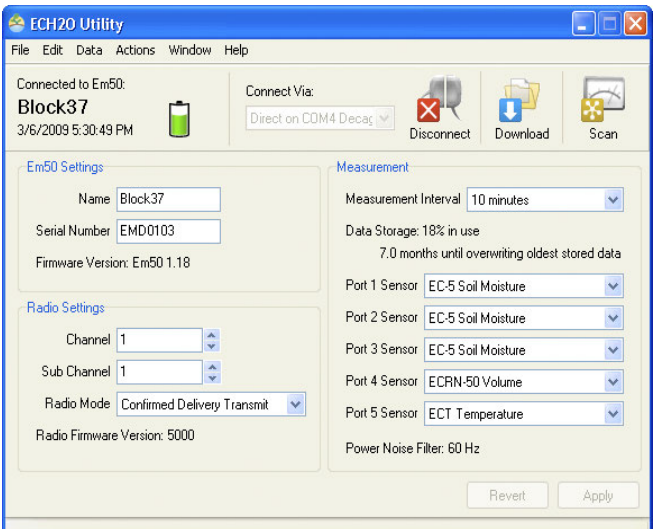
- **Em50G WebViewer**--Use the Em50G WebViewer application when you do not have a DataTrac 3 license to remotely download Microsoft Excel spreadsheets of your

data, and view graphs of your data for the past week through the Decagon Data Service.

DataTrac 3 and ECH_2O Utility Mobile have their own designated manuals. Instructions for ECH_2O Utility and the Em50G WebViewer are included here.

ECH_2O Utility

ECH_2O Utility provides a user-friendly interface for configuring and downloading data from the Em50 logger. After installing the program (see Chapter 3: Setup and Installation for instructions), launch the program. You will see the main screen:



The ECH_2O Utility Main Screen

Here you can set all logger configuration parameters with visual controls. At the top of the program window is a toolbar for interacting with the Em50. To the left is a battery indicator. To the right is the "Connect Via" menu, where you can select a

COM port; the Connect button (which displays "Disconnect" when you are connected to an Em50); the Download button, which downloads data saved on the Em50 onto your computer; and the Scan button, which scans all of the sensors connected to each port on the Em50, and returns a real-time reading. These functions will be described in detail further in this chapter. Below are the most common tasks that can be performed with the ECH_2O Utility, explained in detail.

Common Tasks in ECH_2O Utility

Configuring the Em50/Em50R/Em50G

The Em50 doesn't require any programming. It does have several parameters that control identity and function. To change a parameter, connect to your device, change the desired parameter, then click "Apply" to send the parameter changes to your device. Here is a brief description of each:

Name. Each Em50 device should have a unique name. The default name is the unit's serial number. You can change this to any legal name you want. A legal device name uses upper and lower case letters, numbers, underscores, and hyphens. Spaces and most punctuation are not legal name characters. ECH_2O Utility prevents you from choosing a name containing illegal characters.

Serial Number. When set in the factory, this is a read-only value.

Measurement Interval. The Em50 and Em50R loggers allow you to select a measurement interval between 1 and 1440 minutes while the Em50G allows you to set a measurement interval between 5 and 1440 minutes. A measurement interval of zero (0) or "off" stops the logger from making measurements.

Port Sensors. The Em50 requires you to identify the sensor type for each of the five sensor ports.

Cellular Settings. To turn the cellular network of the Em50G on or off, click the "Configure" button in the "Communication Option" section. The cellular network is active when "Upload data to ECH$_2$OData.com" box is checked and is off when the box is not checked. The Em50G is uploading data to the Decagon Data Service ("on") by default. See Chapter 5. Em50G Cellular Communications for more information on the Em50G.

Choose up to six upload times. Default upload times are: 6-7 AM, 10-11 AM, 1-2 PM, 4-5PM. To conserve battery power, choose fewer upload times.

Click "OK" after making configuration changes. Click "Apply" to save communication settings in your Em50G. Your current settings will show up in the communications option field.

ECH$_2$O Utility helps you evaluate the quality of the cellular connection on your Em50G with the Communication Test feature. Please see Chapter 5. Em50G Cellular Communication for a step-by-step guide to running the Communication Test.

Radio Settings. Only devices that have a radio module will support these options (Em50R, DataStation). See Chapter 6: Em50R Radio Telemetry for more information on using the radio settings.

Downloading Data when Directly Connected

Once the Em50 is properly configured and installed, it will begin making and storing sensor measurements. Stored data can be downloaded from the logger starting at two places in the

logger's memory. The "Download New" option downloads the data stored since the last successful download. The "Download All" option downloads all the data currently stored in the Em50. The "Download" button on the toolbar corresponds to the "Download New" option. Any model of Em50 data logger supports downloading data when directly connected to the logger with ECH_2O System software.

To download data, do the following:

1. Use the USB cable to connect the Em50 to your computer.
2. Choose "Direct on" the appropriate COM port from the "Connect Via" drop-down list and press the "Connect" button. If you encounter connection errors, please see Chapter 11: Troubleshooting or the ECH_2O Utility Help File.
3. Once connected to an Em50, either click the "Download" button on the toolbar, or go to the Data Menu and select a download option as described above.
4. When saving data, the File Save dialog suggests a name based on the connected logger's name and the time and date. However, you can enter any name by typing it into the "File name" field.
5. Choose the file format you prefer then click "Save". ECH_2O Utility will download the data and create the file.

ECH_2O Utility can save your data in several different file formats:

- **Excel Workbook File (.xls)**: Converts the raw down-loaded measurement data into engineering values appropriate for each sensor type. The converted data are saved to sheet 1 of the workbook. Raw data are saved to sheet 2. You can use the raw measurement data to apply custom calibration to your sensor data.

- **DataTrac Data File (.dxd)**: Saves the file in a format that DataTrac can import. Each dxd file contains information about the ECH_2O logger's settings, identity, and status along with the raw data for each sensor.
- **Processed Data Text File (.txt)**: Converts the raw downloaded data into engineering values appropriate for each sensor type. Data are saved as a tab delimited text file.
- **Raw Data (.csv)**: Saves the raw data in the form downloaded from the logger.

NOTE: *The DataTrac file format (.dxd) is a useful way to store data for later manipulation. Each .dxd file contains information about the ECH_2O logger's settings, identity, and status along with the raw data for each sensor. ECH_2O Utility will process a .dxd file into an Excel file or a processed text file. This allows you to re-process your raw data with different settings or file formats as needed.*

Other Data Download Options

An Em50R supports downloading data wirelessly. ECH_2O Utility can establish a two-way radio connection between your computer and a remote Em50R through the Rm1 Radio Modem. Once this connection is established, downloading data from the Em50R is handled just like a download when directly connected to the logger. See Chapter 6. Em50R Radio Telemetry for more information on setting up two-way wireless communications.

The Em50R also supports wireless sensor networks. In this mode, the Em50R transmits measurement data to a DataStation. You can then download the measurement data from all the Em50Rs in your network from one location. See Chapter 6. Em50R Radio Telemetry for more information on setting up logger networks.

The Em50G logger is designed to upload your measurement data to Decagon Data Service using the cellular network. This makes it easy for you to use the internet to download your measurement data from anywhere in the world. Please see Chapter 5: Em50G Cellular Communications for more information.

NOTE: *ECH_2O Utility uses the default conversion equation for each sensor when converting raw data to processed data. For more information about the default conversion equations, please see your logger or sensor manual.*

Erasing Data

If you need to erase the data on your Em50, go to Data > Erase Stored Data. You should erase your data if you change the Em50's configuration settings, such as what type of sensor is in each port. After selecting the Erase option, you will be asked if you want to continue. Click Cancel to return to the program, or Erase Data to continue.

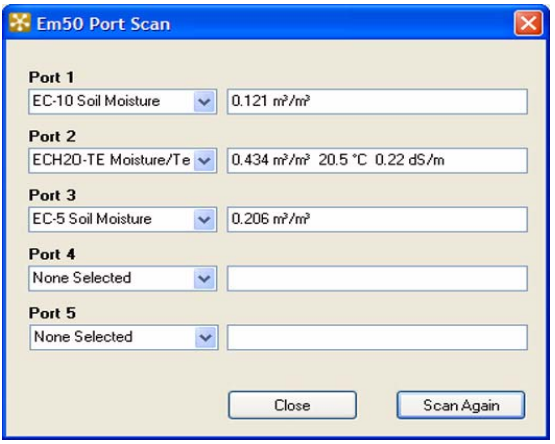
WARNING! Once this feature is activated, ALL stored data will be erased and cannot be recovered!

Instantaneous Measurements (Scan)

The ECH_2O Utility gives you the ability to take real-time sensor measurements with your Em50 logger. This is most useful as a troubleshooting feature to test if a sensor is reading properly. You can also see how sensors react to environmental changes. To take this type of reading:

1. Click the "Scan" button in the toolbar, or go to Actions > Scan Logger Ports. The Em50 will take a reading on each

of the ports, then display a screen similar to the one below.



2. All 5 ports are displayed, along with the measurement for each port in the units appropriate for the sensor. You can change measurement units in the Preferences Menu (see "Measurement Units" in Chapter 5). Click the sensor's name to see the reading as raw data.

The five ports are displayed, along with the measurement for each port in the current selected unit. If nothing is plugged in to a port, the reading for that port will be zero.

NOTE: *Data measured with the scan function will not be stored in the Em50.*

ECH_2O Utility Menus

The ECH_2O Utility features six menus that allow you to access the program's features. This chapter discusses the features of each menu.

The File Menu

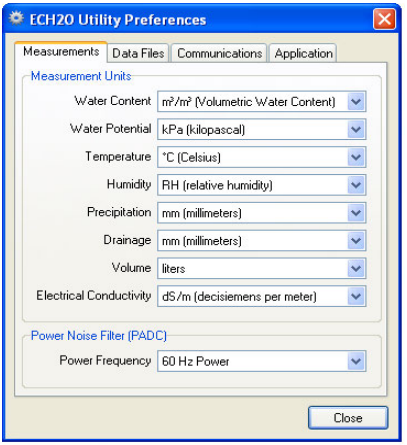
Save Settings File. Selecting the "Save Settings File" option from the File menu will create a data file that contains all of the settings and information associated with the connected Em50. This feature is useful for transferring logger configurations between ECH_2O Utility and ECH_2O DataTrac. By default, the name of the settings file is the name of the selected Em50. After naming the file and selecting where it will be saved, click Save to create the file.

Convert Data File. ECH_2O Utility will "process" or convert raw ECH_2O sensor data to processed data. This feature works by reading a file containing raw data and outputting the processed data into a different file. You can convert DataTrac data files (*.dxd) and EchoLink download files (*.csv or *.txt). Only files saved with ECH_2O Utility and ECH_2O Utility Mobile can be converted to processed files. You can choose to save your processed files as an Excel file or text file.

Edit Menu

The Preferences Menu. The main feature of the Edit Menu is the Preferences menu. The Preferences menu features four tabs for navigation: Measurements, Data Files, Communications, and Application. Below are a list of the most common tasks that can be performed in each tab.

1. Measurements Tab



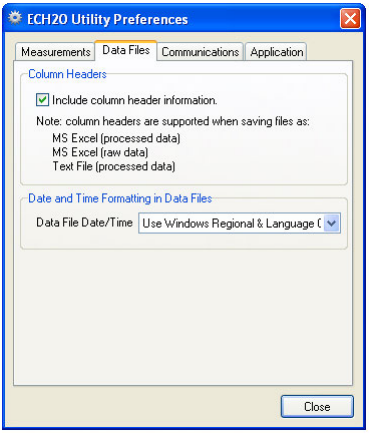
Measurement Units. These are the unit values that will be displayed when downloaded data are saved as Excel, processed, or raw data files. ECH_2O Utility supports displaying some measurement data in multiple units. For example, it allows you to choose degree Celsius or degree Fahrenheit for temperature sensors. To set your preferences for measurement units, choose the "Measurements" tab in the ECH_2O Utility Preferences window.

Locate the type of measurement and select a unit from the drop-down menu next to it. Click "Close" to apply the changes.

Power Noise Filter. The AC electrical power in your office or home can add a subtle amount of noise to the data logger sensor measurements. The logger's Power Noise Filter setting is designed to eliminate this electrical noise that comes from the AC power distribution system. You should set the value of the Power Noise Filter to match the frequency of the power cycle where you live. In North America and most of Asia, this is 60 Hz (the default value). In most of Europe the electrical frequency is

50 Hz. This feature only needs to be set once, as the program will automatically update the filter of each device that it connects to.

2. Data Files Tab

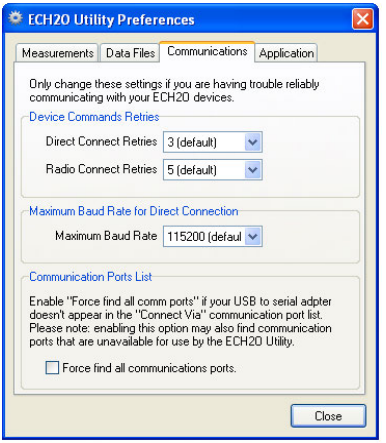


Column Headers. The column header gives each column a title corresponding to the port number, measurement type, and unit. Column headers for saved data files are turned on by default, and apply only to processed and raw MS Excel data, as well as processed text data. De-select "Include column headers" to turn off the column headers for these file types.

Setting Date/Time Format for Data Files. You can control how the date and time values are formatted in the data file. By default, the time and date are formatted using the settings in the Windows Regional & Language Options control panel. You can modify this to display the date and time in dd/mm/yyyy format with either a 12- or 24-hour clock. To change the format, select an option from the menu, then click "Close" to apply the changes.

3. Communications Tab

The Communications preference tab has items that control how the serial communication works between ECH_2O Utility and your Em50. Generally you should not adjust these settings unless you are experiencing problems communicating with your Em50.



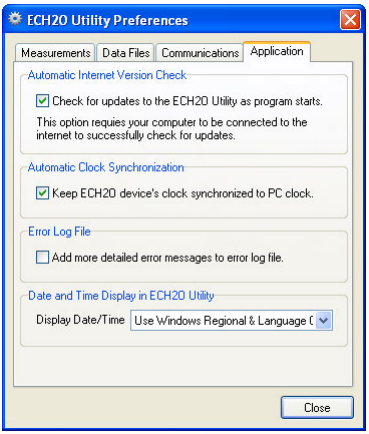
Direct Command Retries. ECH_2O Utility automatically retries commands it sends to your Em50 when there are errors. For most circumstances, the default retries work well. If you experience unreliable communication with your Em50, you can try increasing the Direct Connect Retries.

Maximum Baud Rate. Set a baud rate lower than the default 115,200 baud if you consistently experience serial connection problems.

Communications Port List. ECH_2O Utility is compatible with most USB-to-Serial adapters. Some models of USB-to-Serial adapters are not found by the serial port enumeration feature of

ECH_2O Utility. If your model of USB-to-serial adapter is not recognized, enable "Force find all Communication Ports" in the Preferences Menu by going to the Communication tab, and enabling the check box at the bottom of the screen. Enabling this option may find other serial ports that are not available for use by the ECH_2O Utility (for example, modems installed in your computer).

4. Application Tab



Automatic Internet Version Check. ECH_2O Utility will automatically check for a newer version using Decagons internet version-check engine. When this option is selected, it will notify you when a newer version is available if you are running ECH_2O Utility, and if your computer is connected to the internet. You can turn off the automatic check by un-checking this option. You can manually check for updates any time using the "Check for ECH_2O Utility Updates" option in the Help menu.

Automatic Clock Synchronization. By default, the ECH_2O Utility automatically synchronizes your logger's date and time to

the time set on your computer. You can disable this feature by un-checking this option. You can also update the date and time in your logger any time it is connected by selecting Actions > Set Date/Time.

Error Log File. The ECH_2O Utility keeps a log file of errors and events. Adding more messages to this file is useful for troubleshooting. Check this option to add more error and event messages to the error log.

Date and Time Display in the ECH_2O Utility. You can control how the date and time for your Em50 is displayed in the toolbar status area. By default, the time and date are formatted using the settings in the Windows Regional & Language Options control panel. You can modify this to display the date and time in dd/mm/yyyy format with either a 12- or 24-hour clock.

Data Menu

The Data menu has three options: **Download New Data, Download All**, and **Erase Stored Data**. For more information on these functions, please refer to their respective sections in Chapter 4.

Actions Menu

Connect/Disconnect.

Performs the same function as the connect/disconnect button in the toolbar. It initiates a data communication connection between your Em50 and your computer. You must first connect to your Em50 before downloading data.

Get Settings

This command retrieves all the port and configuration settings from your Em50. These settings are automatically collected

when you connect to your Em50. You can use this option to check to make sure your changes are stored in the Em50.

Apply Settings
Applies the parameters you changed to your Em50. This operates just like the Apply button on the main screen. This option is only available when there are parameter changes available to send to the Em50.

Scan Logger Ports
This option allows you to take readings from each port independent of the others. See the section "Instantaneous Measurements" in Chapter 4 for details and procedures.

Digital Sensor Terminal
The Digital Sensor Terminal is used for SDI-12 addressing and query of our digital SDI-12 sensors. See these sensors' respective manuals for additional information on SDI-12 capabilities.

Set the Date/Time
When you select this action, the ECH$_2$O Utility will set the Em50's time and date to be the same as the time and date on your computer.

Communication Test
When the Em50R or Em50G is connected using ECH$_2$O Utility, use "Communication Test" to see how well your logger's wireless communication is working. If the test suggests that you have a poor connection, you can move to a new location and re-try the communication tests.

Device Tools

The Device Tools submenu contains the following items:

Test Device Firmware. This option is useful in determining if you have any firmware (the internal software that runs the Em50) errors. To initiate a firmware test, select Actions > Device Tools > Test Device Firmware. This will automatically test the integrity of your Em50's firmware, and report if it reads as Bad or Good.

Initialize Radio Module. Resets the radio module to the default setting. This option applies to Em50Rs and DataStations only.

Initialize Device. Initializing your Em50 is a form of a hard reset. ECH_2O Utility resets your Em50 and re-writes all the logger settings. All your measurement data is erased. This option is useful for troubleshooting a logger that is not working as expected.

NOTE: *Initializing your Em50 will delete all stored data. Make sure any data has been downloaded out of the Em50 before initiating a reset.*

Window

The Window Menu contains the Show Terminal command. The terminal window allows you to directly enter commands for your Em50, and is mainly used for troubleshooting and diagnosis.

Help

The Help Menu allows access to the ECH_2O Utility help file, allows you to check for program and firmware updates, and displays information about your copy of the ECH_2O Utility.

ECH$_2$O Utility Help

This menu item opens the help file. It contains some of the information found in this manual.

Send Feedback to Decagon

This menu item helps you send product feedback, bug reports, or feature requests to Decagon. Your computer must be connected to the internet for this feature to work. See Appendix B for more information.

Check for Utility Updates

This function checks for the newest available version of the ECH$_2$O Utility. Make sure you are connected to the internet, then select Help > Check for ECH$_2$O Utility Updates. The program will check to see if there is a newer version available. If there is, it will direct you to the web page where you can download it. To check for a newer version of the ECH$_2$O Utility, choose this menu item. Checking for updates for the ECH$_2$O Utility uses Decagon's version-check web engine. Your computer must be connected to the internet for this feature to work.

Check for Device Firmware Updates

This menu item is only available when you are connected to an Em50 (or other ECH$_2$O device). It compares the firmware version of your Em50 with the latest version available from Decagon. You can download a firmware updater when a new version is available. Your computer must be connected to the internet for this feature to work.

About the ECH$_2$O Utility

This menu item opens the "About" window. You can see the version of your copy of ECH$_2$O Utility here.

Em50G WebViewer

The Em50G WebViewer is a web-based application that can be used to securely connect to the Decagon Data Service to download excel sheets and display weekly graphs of your data. For more specific help than what is provided here, see the Em50G WebViewer Help Files which can be found by clicking the "Help" link on the WebViewer website.

Adding a User

Upon first visiting the Em50G WebViewer, you will be required to either sign in or add an account. If you have already made an account with the Decagon Data Service through either the old Em50G downloader or DataTrac3, your account is already set up and you just have to enter your credentials to sign in. Otherwise, you must make an account. To make an account, begin by clicking on the "Create User" link below the "Sign in" button. This will bring up the Decagon Data Service Registration form. Enter the required information and click on the "Register" button at the bottom. If all goes well with your registration, you should see a page informing you that your registration was successful. Click on the "login" link, and you're ready to add new Em50G loggers to your account.

Add a Subscription

In order to view data from an Em50G, you must first "Subscribe" to it. You are not limited by the number of Em50G loggers you can subscribe to. See the Em50G WebViewer Help Files for more information on subscribing to your data logger.

5. Em50G Cellular Communication

The Em50G data logger is equipped with a GSM/GPRS cellular module that enables the logger to upload sensor measurement data to Decagon Data Service. Your measurement data is available for download directly to your Windows computer at any time, anywhere in the world where you have internet access. To extend your service plan contact Decagon at sales@decagon.com or 1-509-332-5600..

Decagon Data Service

The Em50G uses "push" technology to upload measurement and logger status data to the Decagon Data Service on regular intervals each day. This type of "push" technology allows the Em50G to keep its cellular hardware powered off for most of the time allowing long battery life. The logger uses a unique cryptographic signature and checksum to protect the integrity of the your data as it is transferred over the cellular network and internet as it's uploaded to the Decagon Data Service.

The Em50G keeps track of the data successfully uploaded to the Decagon Data Service. If your logger is unable transfer data during one regularly scheduled session, the data is included in the next upload session.

Once stored in the Decagon Data Service, your measurement data is available for download over the internet. Downloading data does not remove it from the Data Service. It is safely stored for download at any time.

Cellular Service

Decagon makes using the cellular network easy by including the first year of service with the Em50G. Decagon partners with over 200 GSM/GPRS network operators in 120 countries to provide cellular service all over the globe. Decagon has pre-configured your Em50G with an appropriate SIM card for the location where you plan to use your logger. The SIM card and associated service Decagon provides is only for use with the Em50G as outlined by the usage agreement in Appendix C.

NOTE: *Please check with Decagon before moving an Em50G from one country to another to make sure your service plan is appropriate for the new location.*

To extend your service plan or to troubleshoot your cellular service, please contact Decagon or the authorized Decagon Distributor where you purchased your Em50G.

Cellular Coverage

The Em50G requires GSM/GPRS cellular service to upload measurement data to Decagon Data Service. In the USA, the Em50G operates on the T-Mobile and AT&T networks (the Em50G is not compatible with the Verizon or Sprint networks). Outside of the USA, the Em50G should be compatible with technology used by most cellular carriers.

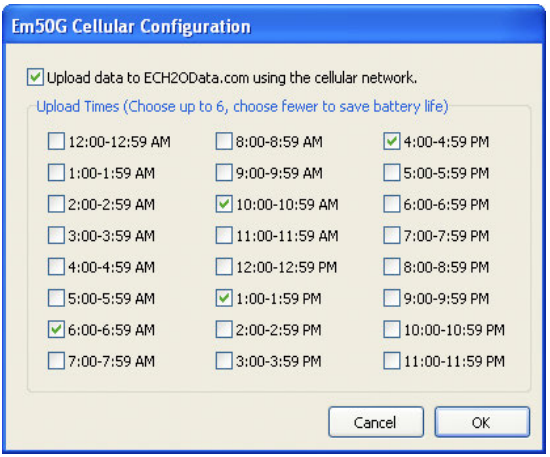
ECH_2O Utility offers a "Communication Test" feature that allows you to evaluate the quality of the cellular network coverage where you plan to install the Em50G. This allows you to evaluate the cellular coverage before installing your logger. Repositioning your logger a short distance may improve your cellular coverage.

For measurement site planning, it may also be useful to consult the network coverage tools offered by each carrier. Please contact Decagon for specific questions about the cellular coverage offered by our partner networks.

In some cases, it may be necessary to use a directional antenna to boost the cellular signal strength of the Em50G to maintain regular data uploads. Please contact Decagon for additional support.

Em50G Configuration and Settings

The Em50G is configured to upload data to Decagon Data Service right out of the box. To start logging and uploading data, configure your logger with the type of sensors installed in each port and turn on sensor logging by choosing a measurement interval. The Em50G will begin uploading data according to the default schedule (uploading between 6-7 AM, 10-11 AM, 1-2 PM, 4-5PM each day).



Use ECH_2O Utility to change these default settings. To turn the cellular network of the Em50G on or off or change the upload times, click the "Configure" button in the "Communication Option" section. The cellular network is active when "Upload data to ECH_2OData.com" box is checked and is off when the box is not checked. In this dialog box, you can choose up to six upload times that correspond to the times when you want to the most up-to-date sensor data available for downloading. The Em50G uses a random time within the hour to reduce resource loads on the cellular network and Data Service. To conserve battery power, choose fewer upload times.

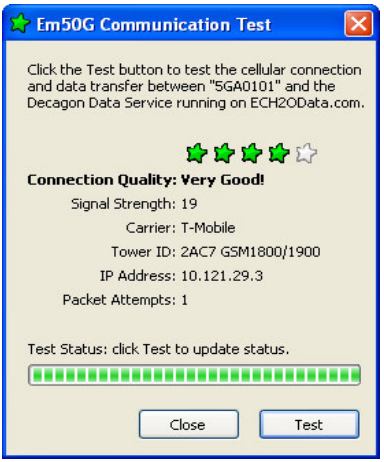
NOTE: *Please contact Decagon if your application requires measuring sensors more often than every 5 minutes or if you need data uploads more often than 6 times a day.*

Click "OK" after making configuration changes. Click "Apply" to save communication settings in your Em50G. Your current settings will show up in the communications option field.

NOTE: *Sensor data recorded by the Em50G while it is configured not to upload data to the Data Service will be stored in the logger, but will not be uploaded to the Data Service. Turning on the upload feature will start uploading data collected on the next measurement interval.*

Communication Testing

ECH_2O Utility helps you check the quality of the cellular communication of your Em50G using the Communication Test feature. Open the Em50G Communication Test dialog by clicking the "Test" button or choosing "Communications Test…" in the Actions menu.



The test takes approximately 30-60 seconds while the Em50G establishes a connection with the cellular network and sends test packets to the Decagon Data Service. Once the tests are finished, the "Connection Quality" field reports connection quality based on cellular signal strength and successful packet transfers. After the initial test is finished, clicking the "Test" button again will update the cellular signal strength and re-send test packets. Subsequent tests are much quicker than the initial test because the Em50G is already connected to the cellular network and the Decagon Data Service. Re-testing your connection quality allows you to find the best spot to install your Em50G. If one test fails, be sure to try the test again.

NOTE: *The cellular radio is on while the "Em50G Cellular Test" dialog window is open. Be sure to close the window when you are done testing to preserve battery power.*

If the connection quality of your Em50G is poor, sometimes moving your logger a short distance will improve the signal

strength. Also consider elevating the antenna by elevating the logger or using an antenna extension cable to improve signal strength. In some cases it may be necessary to use directional antennas to have sufficient cellular signal. Please contact Decagon or your Decagon representative for help choosing the correct antenna for cellular frequencies used at your location.

The Communication Test is checking both the cellular signal strength and the connection to the Decagon Data Service. If the Data Service is temporarily unavailable due internet problems, the connection quality will report a failure even if you have strong cellular signal. If your cellular signal strength is good (above '12') then it is reasonable to expect good connection quality once the Em50G can re-connect to the Decagon Data Service.

NOTE: *The measurement data collected by your Em50G is automatically queued for the next successful connection to the Decagon Data Service. The integrity and continuity of your data is not affected by short term cellular or internet outages.*

Downloading Data

You have two options for downloading the sensor measurement data collected by your Em50G.

Direct Download

Like all Em50 loggers, the Em50G stores more than 36,800 sensor readings for each of the 5 sensor ports. You can use any ECH_2O system software to directly connect to the logger for data download. Your data are always safely stored in non-volatile memory as a backup in unlikely event of data loss on your computer. For downloading instructions when directly connected, see "Downloading Data" in Chapter 4.

Internet Downloading

The Em50G and Decagon Data Service make downloading your measurement data over the internet convenient and easy. Use DataTrac 3 to subscribe to data collected by your Em50G. The Em50G WebViewer web application is also designed to download and display Em50G data

NOTE: *ECH_2O Utility does not connect to the Decagon Data Service for downloading data over the internet. You must use either DataTrac 3 or the WebViewer.*

You can choose to use either DataTrac 3, or the free Em50G WebViewer web application, depending on your needs. DataTrac 3 can be installed from the installation CD that came with your logger manual, or you can install the latest version from www.decagon.com/support/downloads/. To access the Em50G WebViewer, go to www.ech2odata.com/viewer/login/. For more information on accessing and downloading data from the Em50G WebViewer application, see the Em50G Web-Viewer Help Files, found by clicking on the "Help" link on the Em50G WebViewer website.

Downloading with DataTrac 3

When you first launch the DataTrac 3 application, you are prompted to enter your user contact information as shown on the screen on the next page.

Decagon uses this information to link you to your subscribed Em50G so that we can provide customer support in the event your logger isn't working as expected. You can update this information at any time by choosing "User Configuration" from the Settings menu. Once you've completed the user information, you are ready to add new subscription information.

In order to download data over the internet for a specific logger, you must first "subscribe" to that Em50G logger. You may subscribe to any number of Em50G loggers. Remember that during the subscription process you must be connected to the internet. To subscribe using DataTrac 3:

1. Click "set-up", "new" and then "Em50 subscription". The following screen will appear.

2. Enter the unique "Device ID" and "Password" for your Em50G. You will find this information on the brightly colored card that came with your Em50G logger. Keep this card in a safe place.
3. Make sure the "Server" option is set to "ECH$_2$OData.com (Default)".
4. Pick the amount of data you want to include in the first download. If this is the first time you are downloading data from this logger, you should choose the "All Data Points" option. If you are only interested in downloading data uploaded over the last day or last week, choose "Last Day" or "Last Week" respectively.
5. Click "OK". DataTrac 3 will communicate with the Decagon Data Service to verify the information you've entered.

Repeat the above steps for each of your Em50G loggers. You can add new logger subscriptions at any time.

Click the "Download" button to download any new measurement data sent by your Em50G loggers since the last time you downloaded. Data files successfully downloaded for each logger is saved in DataTrac 3's auto-import directory (My Documents\

ECH_2O DataTrac\AutoImport\). When DataTrac 3 launches, it will automatically process the files in this directory by appending this data to the appropriate logger.

NOTE: *DataTrac 3 will list loggers in the "New Devices" section by the logger name when it encounters a logger it hasn't seen before. Select your Em50G by its name, and choose the "Configure" button on the DataTrac toolbar. Set the location information if desired, then press "OK".*

Downloading with Em50G WebViewer

For help on downloading data through the Em50G WebViewer web application, please refer to the Em50G WebViewer Help Files, located under the "Help" link on the WebViewer website.

Managing Subscriptions

The DataTrac 3 application attempts to download data from each logger in the main window. If you want to stop subscribing from a logger permanently, select the logger in the list and choose "Delete Subscription" from the File menu.

The Em50G WebViewer also attempts to download data from each of the Em50Gs you have subscribed to. For help on unsubscribing from loggers, see the Em50G WebViewer Help Files, located under the "Help" link on the WebViewer website.

Sharing Data

The Em50G and Decagon Data Service also make it easy to share your measurement data with a colleague or collaborator. You control who has access to specific Em50G data by providing the unique Device ID and Password pair associated with

each logger (found on the brightly colored card shipped with each Em50G).

NOTE: *You should keep the Em50G Device ID and Password card in a safe place. Don't leave it inside the Em50G logger case. Only share the information on the card with people you wish to have access to the data published by your Em50G logger.*

There is no limit to the number of people who can subscribe to each Em50G. Each subscriber either runs their own copy of the DataTrac 3, or uses their own Decagon Data Service account on the Em50G WebViewer web application. One subscriber's data downloads does not interfere with another subscriber's data downloads.

6. Em50R Radio Telemetry

This chapter gives you a brief overview of the radio telemetry available in the ECH_2O system. This information only applies to Em50R. The ECH_2O system supports two types of radio telemetry: "Two-way" modes and "Transmit" modes. Consider one or both types of radio modes when designing your ECH_2O telemetry system. The "Confirm Delivery Transmit" mode ensure the most complete data transfer and the best battery life. However, there are some unique cases where you may want to use the other available modes.

NOTE: *To utilize the radio communication capabilities of the Em50R, you will also need either a DataStation or an Rm-1.*

ECH_2O telemetry networks require each remote radio logger to have a unique name. Each logger leaves the factory with the name set to the logger's unique serial number. You can easily change the name of the logger to help you identify or organize your data. You should not give two loggers the same name. Two loggers with the same name will interfere with each other when communicating over the radio.

Transmit Radio Telemetry

The Transmit Radio modes help you create a simple network of remote radio loggers all transmitting data to a DataStation radio base station. The DataStation stores data from all the remote loggers in one convenient place. Typically, a DataStation is connected to your computer where you can easily download the data for use in DataTrac 3. Unlike the Two-way Radio

modes, you can't remotely change logger settings when using this mode.

When a logger is in Transmit mode, it only turns on the radio when it has new data to broadcast. For example, when you set the measurement interval in your logger to 60 minutes, the logger stores your data every hour and then broadcasts the data to a listening DataStation. The actual transmit time is randomly delayed for several minutes to prevent two or more radio loggers from interfering with each other.

The Transmit radio modes use less battery power because the radio is off most of the time. The Em50R is designed to work approximately 12 months in Transmit mode.

NOTE: *A DataStation is a receiver. It doesn't cause the remote logger to send data. If your DataStation is powered off for some time, it won't receive data sent by the remote loggers. However, the missing data is still stored in the logger. You can directly connect to the logger to download the missing data.*

Transmit Radio Modes

Use the Radio Tab in the logger settings form to choose one of the following radio modes that support Transmit communication.

Confirmed Delivery Transmit: This is the recommended mode since it is the most robust Transmit radio mode. The radio logger adds a checksum to the data packet before broadcasting the data to a DataStation. The logger then waits for the DataStation to confirm it correctly received the data packet. If the logger doesn't hear the confirmation, it retries sending the packet again. The logger stops trying to transmit to a DataStation after 25 attempts.

Transmit Only: This is the original Transmit radio mode. It doesn't offer the advantages of the Confirmed Delivery Transmit mode. You should use the Confirmed Delivery mode when possible. Em5R (discontinued) loggers only support this Transmit radio mode.

Transmit + Two-way and **CD Transmit + Two-way:** These modes combine the Two-way Radio mode and the Transmit Radio mode. You could use these modes while configuring and testing your radio network. You should not leave your radio logger in these modes because they use the most battery power of all the radio modes. Using Transmit + Two-way and CD Transmit + Two-way radio modes with the wake interval set to 1 or 2 will cause the batteries of your logger to drain very rapidly.

Transmit Best Practices

Transmit modes are most useful when you have three or more loggers installed within radio range of each other. There is no set limit to the number of radio loggers broadcasting to a DataStation. Use this mode for as few as one logger and as many as 50 or more loggers. You should use the Telemetry Test feature of ECH$_2$O Utility to test the connection from your logger to the DataStation.

NOTE: *Em50R loggers must have firmware version 1.12 or later to enable the Confirmed Delivery Transmit mode and Telemetry Test feature. Your DataStation must have firmware version 1.09 or later to receive Confirmed Delivery Transmit mode data packets. Contact Decagon for an application note that covers the steps needed to upgrade your hardware.*

See section on DataStation Networks for step by step instructions for configuring your DataStation and remote radio loggers.

Two-Way Radio Telemetry

The Two-way Telemetry Mode lets you establish a two-way connection with a remote radio logger. Once connected to the remote logger, you can download data and change most settings just like you were connected directly to the logger with a serial cable. Communicating with a remote radio logger requires you to have a Rm1 radio modem connected to your computer. Connecting to the remote radio logger happens through the Rm1.

When a logger is in a Two-way Radio Mode, it turns on its radio every 45 seconds. While the radio is on, the logger listens for connection attempts from a Rm1. If the logger doesn't hear any connection attempts, it turns off the radio. If the logger hears a connection attempt, it leaves the radio on for several seconds listening for login commands from ECH$_2$O Utility. It takes up to 60 seconds to connect to the remote logger.

When you are finished interacting with the remote radio logger, you press the disconnect button. ECH$_2$O Utility sends a "logout" command to the remote logger to indicate the end of the communication session. When the remote logger hears the "logout" command, it waits for 10 minutes before listening for additional connection attempts via the radio (you can always direct connect to your logger). This allows you to connect to other loggers with the same radio settings. Otherwise, the first logger you contacted may reconnect. This would prevent you from connecting to your other loggers.

The Two-way modes generally consume the most power. The Em50R is designed to work for several months in the Two-way modes.

Two-way Radio Modes

Use the Radio settings section of ECH_2O Utility to choose one of the following radio modes that support two-way communication.

Two-way 24-hour: The radio logger listens for connection attempts every 45 seconds, 24 hours a day. This mode uses a substantial amount of batter power. Expect batteries to last for approximately 3 months.

Two-way 6:00-18:00: The radio logger listens for connection attempts every 45 seconds between 6 AM and 6 PM. The logger doesn't use the radio between 6 PM and 6 AM to conserve battery power, by not listening for connection attempts during the night. Expect batteries to last for approximately 6 months in this mode.

Transmit + Two-way and **CD Transmit + Two-way**: These modes combine the Two-way Radio modes and the Transmit Radio modes. You could use these modes while configuring and testing your radio network. You should not leave your radio logger in these modes because they use the most battery power of all the radio modes. Expect batteries to last for approximately 3 months in this mode.

NOTE: *Using Transmit + Two-way and CD Transmit + Two-way radio modes with the wake interval set to 1 or 2 will cause the batteries of your logger to drain very rapidly.*

Two-way Best Practices

Two-way modes are most useful when you have a small number (one, two, or three) of remote radio loggers you wish to contact. If you have three or more loggers installed within radio range of each other, consider using one of the Transmit

modes. The Two-way modes also allow you to mount an Rm1 in your vehicle and interact with the remote logger while in radio range.

See section on Connecting via a Radio Modem for step by step instructions for establishing a two-way connection with a remote radio logger.

Radio Settings

For two radio devices to communicate they must share the same radio settings. An Rm1 radio modem can only connect to a remote radio logger with the same radio settings. A DataStation will only receive data from loggers with the same radio settings as the DataStation. Set the Radio Channel to the same value for all the devices on the same network. Set the Radio Sub Channel to the same value for all the devices on the same network.

Radio logger networks with different values set for the Radio Channel use different frequency-hopping sequences, and therefore experience minimal interference between groups. Radio logger networks with the same Radio Channel value but different Radio Sub Channel values can interfere with each other, but can't communicate with each other. This interference can also cause additional battery drain in the radio logger.

The default values for Radio Channel and Sub Channel are zero. Use ECH_2O Utility to choose other values.

Radio Performance

The maximum range of the radio modules in the radio logger and DataStation are affected by the environment, installation

method, and antenna choice. Maximizing the range of your radio network requires you to consider all of these factors.

Buildings, hills, vegetation, vehicles and other environmental obstructions will shorten the radio's range – sometimes drastically. You should ensure a clear, open path between radio devices. Also, radio frequency (RF) interference in the environment around the radio can reduce the usable range (even if not using the same radio frequencies). You should consider nearby growing vegetation when designing and testing your radio network. Some radio networks work fine when the vegetation is sparse, yet may fail when vegetation is full.

You can increase the effective transmit range by maximizing the height above ground of the radio antenna. This helps ensure a clear path for the radio signals and reduces the amount of signal absorbed by the earth. Use an antenna extension cable to help you position your antenna when it isn't practical to install your logger higher off the ground. If you mount your radio logger to a metal pole, you should mount your antenna to the top of the metal pole so it is free to radiate the signal above the pole.

Replacing the stock antenna on your radio device with a high-gain antenna can greatly increase the radio range. Consider using a directional Yagi antenna or a high-gain omni-directional antenna when you want to extend the range of your radio network. A high-gain antenna can also help overcome the effects of unavoidable environmental obstructions.

The ECH_2O telemetry system also supports a simple relay for use with Transmit Mode networks. Combining a relay and high-gain antennas allows radio devices to communicate over

very long distances. Contact Decagon for more information on using a relay in your radio network.

Connecting via Rm-1 Radio Modem

Connecting to an Em50R via a Rm1 is different than connecting via your USB cable. Keep notes concerning the Em50R name and radio settings to make the rest of the system configuration easier to accomplish.

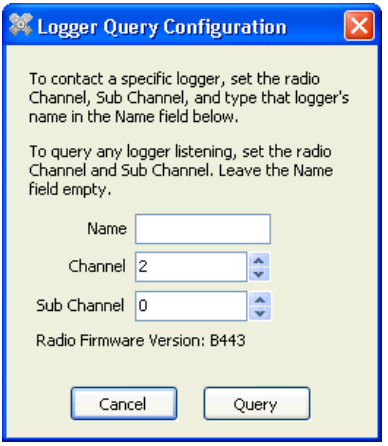
Before you can use the telemetry options of your Em50R, you must configure the Em50R by connecting it directly to your computer using your USB cable. Connect using ECH_2O Utility or DataTrac 3 and set the Em50R's Channel, Sub Channel, and Radio Mode. See the section on Configuring in ECH_2O Utility for additional information on configuring the Em50 series loggers. The Channel can be set from 0 to 6 inclusive (default is 0). The Sub Channel can be set from 0 to 65534 inclusive (default is 0). To use the radio logger with an Rm1, the Radio Mode has to be set to one of the Two-way modes.

If the Two-way 6:00-18:00 mode is chosen, then connection via the Rm1 can only take place between the hours of 6:00 AM through 6:00 PM. This mode was designed to improve battery life by not keeping the radio on constantly. The other Two-way modes can be connected to 24 hours a day.

After setting the Radio Mode, click the "Apply" button in ECH_2O Utility. Disconnect from the Em50R logger. Now, connect your computer to the Rm1 by using a standard 9-pin serial cable. (A USB version of the Rm1 is also available.)

Choose the correct communication port in the "Connect Via" drop-down menu. For example, if your Rm1 is physically con-

nected to your computers COM1 communication port, you would choose "Rm1 on COM1 Communication Port" in the "Connect Via" menu. Click the "Connect" button.



The Logger Query Configuration form will appear. To connect to a specific Em50R, type the logger's Name, Channel, and Sub Channel. After typing the name, click the Query button. If you want to connect to any available Em50R, pick the correct Channel and Sub Channel, but leave the Name field blank.

NOTE: *To connect to a radio logger, the radio Channel setting must be the same for both the logger and the Rm1. The radio Sub Channel setting must also be the same for both the logger and the Rm1.*

The Connection Progress screen appears as ECH_2O Utility tries to establish a radio connection with the remote logger through the Rm1. The connection process can take up to 60 seconds while ECH_2O Utility sends a logger "wake up" signal and retries the connection attempt.

When ECH_2O Utility connects to a remote radio logger, it shows the signal strength of the connection with the radio signal strength icon on the status bar. Click on the radio signal strength icon to see the signal strength percent in the message area.

See Chapter 9: Troubleshooting if ECH_2O Utility fails to connect to your remote logger.

Once ECH_2O Utility establishes a two-way radio connection with a remote logger, you can interact with the logger just like a direct connection.

NOTE: *You cannot change the radio Channel or radio Sub Channel settings in the remote logger while connected via the Rm1.*

DataStation Networks

Configure a DataStation

After establishing a connection set the Channel and Sub Channel. Channel can be set from 0 to 6 inclusive (default is 0). The Sub Channel can be set from 0 to 65534 inclusive (default is 0).

Note the Channel and Sub Channel settings chosen. Click the "Apply" button to save the settings to the DataStation. For easy data downloading and telemetry testing, leave the DataStation plugged into your computer and your powered at all times.

Configure an Em50R Logger for use with the DataStation

To use one or more Em50R loggers with a DataStation the Radio Mode has to be set to one of the Transmit modes. We recommend the "Confirm Delivery" transmit mode.

Connect the Em50R to your computer or handheld device using the appropriate cable. Start ECH_2O Utility, ECH_2O Utility Mobile or DataTrac. Once you're connected, set the radio Channel and Sub Channel settings to exactly the values chosen for the DataStation previously. Set the Radio Mode to Confirmed Delivery Transmit. This mode provides a method for confirming the delivery of the data which greatly increases the ability of the system to successfully transfer the data. The Transmit + Two-way modes are there for use as troubleshooting aids. Set the measurement interval and pick the sensors that will be plugged into each port. See the section on Configuring in ECH_2O Utility for additional details on configuring the Em50 series. After setting the Radio Mode, click the "Apply" button.

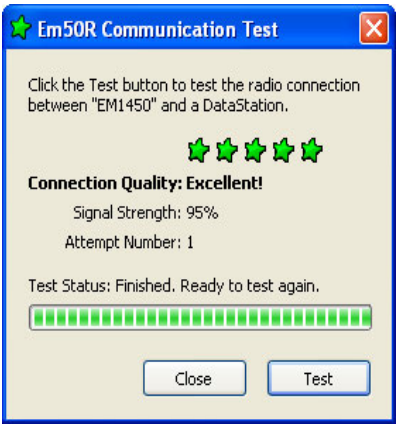
NOTE*: ECH_2O Utility only shows the radio modes compatible with your radio logger model and firmware version. If you don't see the "Confirmed Delivery Transmit" radio mode option, then your radio logger may not support this option. If you are using an Em50R logger you will need to update the firmware to version 1.12 or newer. Visit www.decagon.com/support/downloads for the most current firmware and software modes.*

Communication Test

Before finding a permanent location for your Em50R, perform a communication test to verify the quality of the radio communication. However, make sure your DataStation is properly configured and powered during your communication test.

In your field area, connect your Em50R to either a laptop or handheld device using the appropriate cable and press connect. Ensure that your radio channel and subchannel as well as your

transmit mode are the same as your DataStation. Choose "Communication Test" from the Actions Menu.



Click the Test button and the test will begin. When the test has finished you will be presented with the results of the test. Five stars signifies excellent communication. One star means that all of your data are being transmitted, but multiple tries are necessary. The more attempts to send data means more power is used. Therefore, one star is adequate for data transmission, but will decrease battery life.

You may have to relocate the radio logger while doing the Telemetry Test in order to find the best connection quality. Once you have found the radio logger location that provides the best connection quality, install the radio logger at that location.

NOTE: *Communication Test only works with Em50 loggers running firmware 1.12 or newer.*

Download Collected Data

After the DataStation is configured, it will automatically collect data from Em50R loggers within range and sharing the same channel and sub channel. After data is collected, you can retrieve the data for permanent storage and analysis. DataTrac is best suited for this application.

To download and view data from the DataStation, start DataTrac. In the DataTrac menu, pick the DataStation you want to connect to and click "connect." Click the "Download New Data" button. The Downloading DataStation Data screen will appear and provides a progress bar displaying the download progress.

Data Processing

DataTrac automatically sorts the data collected by the DataStation and associates the data with the correct logger. However, unless you used DataTrac to also configure your Em50R loggers, DataTrac will not know your logger's name and which sensors are plugged into each port. To add this information to your data set, click on the appropriate Em50R in the logger tree and select "Configure."

If DataTrac is not an option, ECH_2O Utility can be used to retrieve data from your DataStation. ECH_2O Utility gives you several choices for the file type when downloading data from a DataStation. See Chapter 5: Using ECH_2O Utility, for more information. If you choose processed or raw data file formats, ECH_2O Utility walks you through processing the data for each logger it recorded data for. It prompts you for the logger type and sensor types for each logger. This information is necessary for ECH_2O Utility to process the data correctly.

7. Compatible Sensors

The Em50 logger is only compatible with sensors made by Decagon. This chapter gives a list of compatible sensors. To learn more about individual sensors and their respective calibrations, please visit http://www.decagon.com/support/sensor-calibration-master-list.

Soil Water Content Sensors

10HS, EC-5 High Frequency Soil Moisture
5TM Soil Moisture and Soil Temperature
5TE, GS3, RS3 Soil Moisture, Soil Temperature, Soil EC

Soil Water Potential Sensor

MPS-2 Water Potential and Temperature Sensor

Leaf Wetness Sensor

LWS Leaf Wetness Sensor

Temperature Sensors

ECT Air Temperature Sensor
RT-1 Rugged Soil Temperature Sensor

Rain Gauges Sensors

ECRN-50 Low Resolution Rain Gauge
ECRN-100 High Resolution Rain Gauge

Temperature and Relative Humidity Sensor

EHT Temperature/RH Sensor

Radiation Sensors

PYR Solar Radiation Sensor
QSO-S PAR Photon Flux Sensor

Wind Sensor

Davis Cup Anemometer

Deep Drainage Sensors

G1/G2 Drain Gauge

Irrigation Switch

PS-1 Pressure Switch

Miscellaneous Sensors

ECRN-50 Volume
Millivolt (0-3000 mv input)
Millivolt (0-1500 mv input)
Pulse Counter
Flow Meter

Discontinued Sensors

EC-10, EC-20 Classic Soil Moisture
EC-TM Soil Moisture and Temperature
ECH2O-TE Soil Moisture, Soil Temperature, Soil EC
MPS-1 Dielectric Water Potential Sensor

8. Caring for the Em50

Replacing the Batteries

If installed correctly, the Em50 requires little maintenance. The main requirement is that batteries need to be replaced when their charge becomes too low. When the battery life indicator in ECH_2O Utility shows your Em50's batteries are less than 5%, you need to replace them.

NOTE: *Installing or changing the batteries in your Em50 resets the internal real-time clock. You must connect to your Em50 using any ECH_2O system software to reset the logger's clock immediately after changing the batteries. If you don't set the logger's clock, the time and date associated with each measurement will be incorrect.*

Long-Term Maintenance

When caring for the Em50 over an extended period of time, be sure to do the following periodically:

1. Check the battery holders and make sure they are clean and free of corrosion.
2. Check that the sensor ports are clean, and that the sensors are making good contact with the ports.
3. Check case gaskets and sensor cable strain relief.

9. Troubleshooting

Although the Em50 has been designed for durability and built to the highest manufacturing standards, problems may occasionally occur. This chapter details the most common problems that you may encounter, and their solutions. If you have a problem not described here or that this section cannot remedy, contact Decagon by email at support@decagon.com or call us at at 1-509-332-5600.

Troubleshooting Serial Ports

PROBLEM: The ECH_2O Utility tells me the communication port I want to use is in use by another application, but I don't think any other programs are running.

SOLUTION: Some PDA synchronization programs monitor serial communication ports. Disable Microsoft's ActiveSync or Palm's HotSync system software while trying to use the serial port with the ECH_2O Utility.

PROBLEM: My USB to Serial adapter is not showing in the communication port picker.

SOLUTION: Enable "Force find all Communication Ports" in the Preferences Menu by going to the Edit Menu, clicking Preferences, then the Communication tab, and enabling the check box at the bottom of the screen. Enabling this option may find other serial ports that are not available for use by the ECH_2O Utility (for example, modems installed in your computer).

Troubleshooting DirectConnection

PROBLEM: ECH_2O Utility tells me it can't connect to my device.

SOLUTION: Try one or more of the following to make sure there is a connection to the ECH_2O device:

If you are using the accompanying USB cable, download the USB driver from www.decagon.com/support/downloads. Check your serial port choice. Make sure the "Connect Via" drop-down menu shows the name of the serial port you are using to physically connect to your logger or DataStation. For example, if our logger is physically connected to COM1, the "Connect Via" control should be set to "Direct on COM1 Communication Port".

Check that your serial cable is securely plugged into your logger or DataStation and your Computer.

Make sure your logger has good batteries or your DataStation is plugged in. Try pressing the reset button on your logger or DataStation.

NOTE: *Serial Cables can fail. If you suspect your serial cable may be the problem, try connecting to a second logger. If you can connect, the problem is probably the first logger. If you can't connect to the second logger either, the problem may be your cable. Try using a spare Decagon Serial Cable Adapter or the USB cable if you are having trouble connecting to a logger.*

PROBLEM: ECH_2O Utility keeps reporting it lost the connection to my device.

SOLUTION: This rarely happens for a direct connection. Please check or replace your serial cables. You can also increase the number of times ECH_2O Utility tries sending commands to the logger or DataStation. Increase the Direct Connect Retries on the Communication tab of the Preferences form.

Troubleshooting Radio Connections

PROBLEM: ECH_2O Utility tells me my radio modem isn't responding.

SOLUTION: Make sure your serial cable is securely attached to your computer and your Rm1. Your Rm1 should have power and be turned on.

PROBLEM: ECH_2O Utility tells me it can't connect to my radio logger when I'm using an Rm1.

SOLUTION: Try one or more of the following to make sure there is a good radio connection to your remote logger:

- Make sure your DataStation and Em50R have the same Channel and Subchannel and that the DataStation is being continuously powered.
- Make sure you are within radio range of the remote logger by performing a telemetry test. If this is the problem, increase the radio signal strength to your logger by moving closer to your logger or using a high-gain antenna to see if you can establish a radio connection.
- Make sure the antenna on the logger and the Rm1 are securely fastened to the radio module.

- Check the Radio Channel and the Radio Sub Channel settings you are using on your remote loggers and Rm1. See Chapter 7, Connecting via a Radio Modem, for how to configure your radio settings.
- Make sure you wait ten minutes between connection attempts for the same logger. If you just disconnected from a logger, you must wait for ten minutes before that logger will accept radio connections (you can always direct connect to your logger).
- Make sure your logger has good batteries. Try pressing the reset button on your logger.

PROBLEM: ECH_2O Utility keeps reporting it lost the connection to my device.

SOLUTION: This can happen when the radio connection is lost. Try increasing the radio signal strength by moving closer to the remote logger or using a high-gain antenna. You can also increase the number of times ECH_2O Utility tries sending commands to the logger. Increase the Radio Connect Retries in the Communications tab on the Preferences form.

Troubleshooting Data Issues

PROBLEM: ECH_2O Utility tells me there is no new data for downloading.

SOLUTION: Make sure the logger is configured to measure data. Make sure the measurement interval is set to a number greater than zero. Try pressing the reset button if the logger does have a non-zero measurement interval.

PROBLEM: My sensor data shows "* * *" in the Scan window.

SOLUTION: The three asterisks mean the raw data measured by the logger is out of expected range for the sensor. This could be caused by a broken sensor. Make sure the sensor is fully inserted into the logger's sensor port. Make sure the sensor type shown in the Scan window matches the sensor actually connected to your logger.

PROBLEM: My sensor data doesn't seem to be correct.

SOLUTION: There are many issues that affect the quality of the sensor measurement. Please see the user manual of your particular sensor for help troubleshooting the data collected by your sensor or contact Decagon by phone at 1-509-332-5600 or by email at support@Decagon.com.

Troubleshooting Logger Issues

PROBLEM: My logger stopped making measurements.

SOLUTION: Make sure the measurement interval is not set to 0. The Em50 does not make any measurements when the measurement interval is set to zero.

Try pushing the reset button. Try initializing your Em50 if a reset isn't enough to get the logger measuring sensors again. Connect to the logger and choose "Initialize Device..." from the Device Tools sub-menu in the Actions menu. Initializing your Em50 will erase any stored data so you should download any data you want to keep before choosing this option.

PROBLEM: My logger doesn't seem to be working correctly or reliably.

SOLUTION: Try pressing the reset button on the logger. This resets the logger's firmware. You can also try connecting to the logger and testing the integrity of the firmware. Choose "Test Device Firmware" from the Device Tools menu of the Actions menu. Contact Decagon for help reloading the firmware if ECH_2O Utility reports the device firmware is corrupt. If the firmware tests good and your logger is still not working correctly, please contact Decagon for repair or replacement.

Appendix A:

Em50 CE Compliance

Application of Council Directive:	89/336/EEC
Standards to Which Conformity is Declared:	EN61326 : 1998 EN55022 : 1998
Manufacturer's Name:	Decagon Devices, Inc. 2365 NE Hopkins Ct. Pullman,WA 99163
Type of Equipment:	Data collection system
Model Number:	Em50
Year of First Manufacture:	2002

This is to certify that the Em50, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA meets or exceeds the standards for CE compliance as per the Council Directives noted above. All instruments are built at the factory at Decagon and pertinent testing documentation is freely available for verification.

Em50R/DataStation/Rm1 CE Compliance

Application of Council Directive: 89/336/EEC

Standards to Which Conformity is Declared:	EN61326 : 1998 EN55022 : 1998
Manufacturer's Name:	Decagon Devices, Inc. 2365 NE Hopkins Ct. Pullman, WA 99163
Type of Equipment:	Data collection system
Model Number:	Em50R 2.4 GHz Rm1 2.4 GHz, DataStation 2.4 GHz
Year of First Manufacture:	2002

Restrictions:
France: Current regulations in France stipulate that these devices may be used indoors only. Outdoor use on private property is subject to authorization from the French Telecommunications Regulatory Authority. Outdoor use on public property is currently prohibited. For more information, see www.ero.dk.

FCC Compliance

The following FCC statement applies to the Em50, Em50R, Em50G, DataStation, and Rm1.
This device complies with part 15 of the FCC Rules. Operation is subject to the following conditions:

1. This device may not cause harmful interference.
2. This device must accept any interference received, including interference that may cause undesired operation.

The Em50R, DataStation, and Rm1 contain one of the following modules:

FCC ID: OUR9XSTREAM IC: 4214A-9XSTREAM
FCC ID: OUR-24XSTREAM IC: 4214A 12008

The Em50G contains the following module:

FCC ID: IHDT56HQ1 IC: 109O-HQ1

Information for users
Changes or modifications to the EM50 series loggers not expressly approved by Decagon Devices, Inc. could void FCC compliance and thus the user's authority to operate the equipment.

NOTE*:* This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate

radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct th***e*** interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult Decagon Devices or your local representative for support.

Em50G CE Compliance

Application of Council Directive:	89/336/EEC 1999/5/EC
Standards to Which Conformity is Declared:	EN61326 : 1998 EN55022 : 1998
Manufacturer's Name:	Decagon Devices, Inc. 2365 NE Hopkins Ct. Pullman, WA 99163
Type of Equipment:	Data collection system
Model Number:	Em50G
Year of First Manufacture:	2010

Cellular Module Information

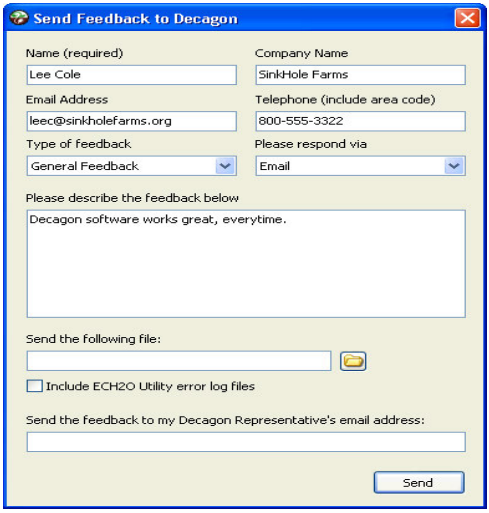
The Quad-band GSM/GPRS cellular module in the Em50G has been tested and approved under the standards and regulations listed below:

FCC part 12,22,24. FCC ID: IHDT56HQ1
Industry Canada (IC) 109O-HQ1
R&TTE - LVD 2006/95/EC
Standards: EN301 489-1 & 7, EN60950
EU Product Approval Number: G24-L
GCF 3.27.1
NAPRD 3.14.0
PTCRB

Appendix B:

Send Feedback to Decagon

Decagon Software makes it easy to send feedback, bug reports, and feature requests to Decagon or your Decagon Distributor. Choose "Send Feedback to Decagon..." from the help menu. This opens the window shown below.



Enter your name, company name, and other contact information. Tell us what type of feedback you are sending (General Feedback, Feature Suggestions, Bug Report, or Other). Indicate how you want us to respond to your feedback (Email or Telephone).

Use the description area to give details for your feedback. If you are reporting a bug, it is very helpful for you to tell us what steps you took for the bug to happen and any error message you saw. By default, bug reports also include the software error files.

You can send Decagon a file using this form too. This is useful for sending data files that you have questions about.

If you work directly with a Decagon representative, put their E-mail address in the field at the bottom of the form. This sends the contents of the form to them. Your Decagon representative can follow-up with you directly.

Appendix C:

Em50G User License Agreement

1. CONTRACT FORMATION

The use of the Em50G ("Device") is governed by the terms and conditions set forth herein. Please read these terms and conditions carefully. If you use or activate the equipment you agree to be bound by these terms and conditions. If you do not accept and agree to be legally bound by these terms and conditions, please do not use the equipment. If you choose not to accept these terms and conditions you may return the Em50G along with all original packaging and accessories for a refund of the purchase price less the cost of shipping and handling.

2. WIRELESS CONNECTIVITY

Decagon provides wireless connectivity for your EM50G for uploading of measurement data and logger status information-under a reseller licensing agreement. You will be charged a fee for wireless connectivity for your use of wireless services on your Device. Decagon reserves the right to discontinue wireless connectivity at any time or to otherwise change the terms for wireless connectivity at any time, including, but not limited to (a) limiting the frequency and amount of data that may be transferred using wireless connectivity and (b) changing the amount and terms applicable for wireless connectivity charges.

3. COVERAGE AND SERVICE INTERRUPTIONS

You acknowledge that if your Device is located in any area without applicable wireless connectivity, you may not be able to use some or all elements of the wireless services. Decagon is

not responsible for the unavailability of wireless service or any interruptions of wireless connectivity.

4. YOUR CONDUCT

You agree you will use the wireless connectivity provided by Decagon only in connection with services Decagon provides for the Em50G. You may not use the wireless connectivity for any other purpose. Unless specifically indicated otherwise, you may not sell, rent, lease, distribute, broadcast, sublicense or otherwise assign any rights to wireless services. You may use the Em50G Software only on the Em50G. You may not sell, rent, lease, lend, distribute or sublicense or otherwise assign any rights to the Software in whole or in part. You may not, and you will not encourage, assist or authorize any other person to, modify, reverse engineer, decompile or disassemble the Em50G or the Software, whether in whole or in part, create any derivative works from or of the Software, or bypass, modify, defeat or tamper with or circumvent any of the functions or protections of the Em50G or Software.

5. AUTOMATIC UPDATES

In order to keep your Software up-to-date, Decagon may automatically provide your Device with updates/upgrades to the Software.

6. EXPORT REGULATIONS

You agree to comply with all export and re-export restrictions and regulations of the Department of Commerce and other United States agencies and authorities, and not to transfer, or encourage, assist or authorize the transfer of the Software to a prohibited country or otherwise in violation of any such restrictions or regulations.

7. GOVERNMENT END USERS

The Software is a "Commercial item" as that term is defined at 48 C.F.R. §2.101, consisting of "Commercial Computer Software" and "Commercial Computer Software Documentation," as such terms are used in 48 C.F.R. §12.212 or 48 C.F.R. §227.7202, as applicable. Consistent with these provisions, the Software is being licensed to U.S. Government end users (a) only as a Commercial item and (b) with only those rights as are granted to all other end users pursuant to the terms and conditions of this Agreement.

8. NO ILLEGAL USE & RESERVATION OF RIGHTS

You may not use the Em50G, or the software for any illegal purpose. You acknowledge that the sale of the Em50G to you does not transfer to you title to or ownership of any intellectual property rights of Decagon or its suppliers. All of the Software is licensed, not sold, and such license is non-exclusive.

9. DATA STORAGE

The Em50G and Software will provide Decagon with data about your Device and its interaction with the software and information related to the content on your Em50G may be stored on servers in the United States at Decagon headquarters. You agree to assume sole responsibility to backup and store your data collected by the Em50G and Software.

10. Data Security and Privacy

While the Em50G and Software use cryptographic methods to protect the integrity of data transfers, Decagon does not guarantee privacy of measurement data or Device status information collected and transferred by the Em50G. You are solely responsible for the security of the Device access passwords issued to you by Decagon.

11. PATENTS

The Em50G and/or software used in association with the Em50G may be covered by one or more patents or pending patent applications, and/or copyright and trademarks or pending applications.

12. TERMINATION

Your rights under this Agreement will automatically terminate without notice from Decagon if you fail to comply with any term of this Agreement. In case of such termination, you must cease all use of the Software and Decagon may immediately revoke your access to the Service or to Digital Content without notice to you and without refund of any fees. Decagon's failure to insist upon or enforce your strict compliance with this Agreement will not constitute a waiver of any of its rights. You may terminate the service at any time, but you will be responsible for all payments under the data services through the end of the term.

13. DISCLAIMER OF WARRANTIES

YOU EXPRESSLY ACKNOWLEDGE AND AGREE THAT USE OF THE EM50G, SOFTWARE AND DATA STORAGE IS AT YOUR SOLE RISK. *EXCEPT FOR THE ONE-YEAR LIMITED WARRANTY,* THE EM50G, SOFTWARE AND DATA STORAGE ARE PROVIDED "AS IS" WITH ALL FAULTS AND WITHOUT WARRANTY OF ANY KIND AND DECAGON AND ITS SUPPLIERS AND LICENSORS DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY, QUIET ENJOYMENT AND NON-INFRINGEMENT OF THIRD-PARTY RIGHTS. NO ORAL OR WRITTEN INFORMATION OR ADVICE GIVEN BY DECAGON OR AN AUTHORIZED REPRESENTATIVE OF DECAGON SHALL CRE-

ATE A WARRANTY. THE LAWS OF CERTAIN JURISDICTIONS DO NOT ALLOW THE DISCLAIMER OF IMPLIED WARRANTIES.

14. LIMITATION OF LIABILITY

LIMITATION OF LIABILITY TO THE EXTENT NOT PROHIBITED BY LAW, NEITHER DECAGON NOR ITS SUPPLIERS OR LICENSORS SHALL BE LIABLE TO YOU FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES FOR BREACH OF ANY EXPRESS OR IMPLIED WARRANTY, BREACH OF CONTRACT, NEGLIGENCE, STRICT LIABILITY OR ANY OTHER LEGAL THEORY RELATED TO THE EM50G, SOFTWARE AND DATA STORAGE, INCLUDING, BUT NOT LIMITED TO, ANY DAMAGES ARISING OUT OF LOSS OF PROFITS, REVENUE, DATA OR USE OF THE EM50G OR SOFTWARE OR ANY ASSOCIATED PRODUCT, EVEN IF DECAGON HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN ANY CASE, DECAGON'S AGGREGATE LIABILITY UNDER THIS AGREEMENT SHALL BE LIMITED TO THE AMOUNT ACTUALLY PAID FOR THE DEVICE. THE LAWS OF CERTAIN JURISDICTIONS DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES.

15. WASHINGTON LAW APPLIES

The laws of the state of Washington, without regard to principles of conflict of laws, will govern this Agreement and any dispute of any sort that might arise between you and Decagon.

16. DISPUTE RESOLUTION

By using the Em50G you agree to jurisdiction and venue of any dispute arising out of this agreement by the Whitman County Court unless the parties agree to a different dispute resolution process in writing.

17. SEVERABILITY

If any term or condition of this Agreement shall be deemed invalid, void, or for any reason unenforceable, that part shall be deemed severable and shall not affect the validity and enforceability of any remaining term or condition.

18. AMENDMENT

Decagon reserves the right to amend any of the terms of this Agreement at its sole discretion by sending an amended agreement in writing to you by first class mail or email. Your continued use of the Device and Software after the effective date of any such amendment shall be deemed your agreement to be bound by such amendment.

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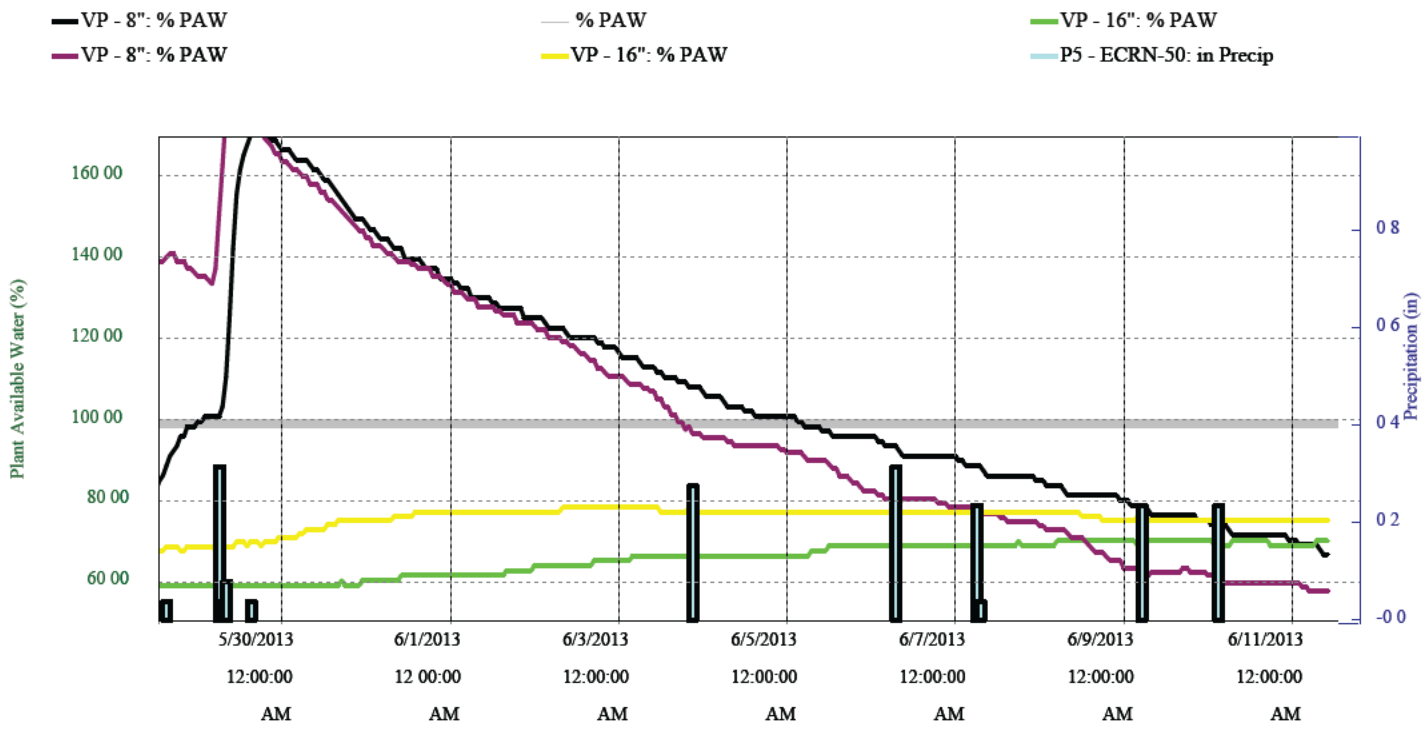
ARCADIS

Appendix E

Data Report Examples

K22_13

Location: (Grower name)
Start: 5/28/2013 12:52:00 PM
Stop: 6/11/2013 12:52:00 PM



	P5 - in Precip ECRN-50	VP1 % PAW	VP2 % PAW	VP3 % PAW	VP4 % PAW
Avg:	n/a	106.90	65.62	102.63	75.77
Min:	n/a	66.79	59.21	57.83	67.75
Max:	n/a	171.21	70.14	179.67	78.37
Total:	1.85	n/a	n/a	n/a	n/a
Events:	11	n/a	n/a	n/a	n/a

AGRIMANAGEMENT® INC.
AGRICULTURAL CONSULTANTS
408 N. 1st St.
Yakima, WA 98901
Tel: (509) 453-4851
Fax: (509) 588-1672
Web: agrimgt.com

AGRIMETRIC SERVICES – MEASURING CROP NEEDS FOR GREATER PROFITS

Soil Moisture Report

FieldID: Home CP
Crop: Silage Corn
Stage: Avg Height 27"

Acres: 152.6
Irr: Center Pivot
Color: Normal Green

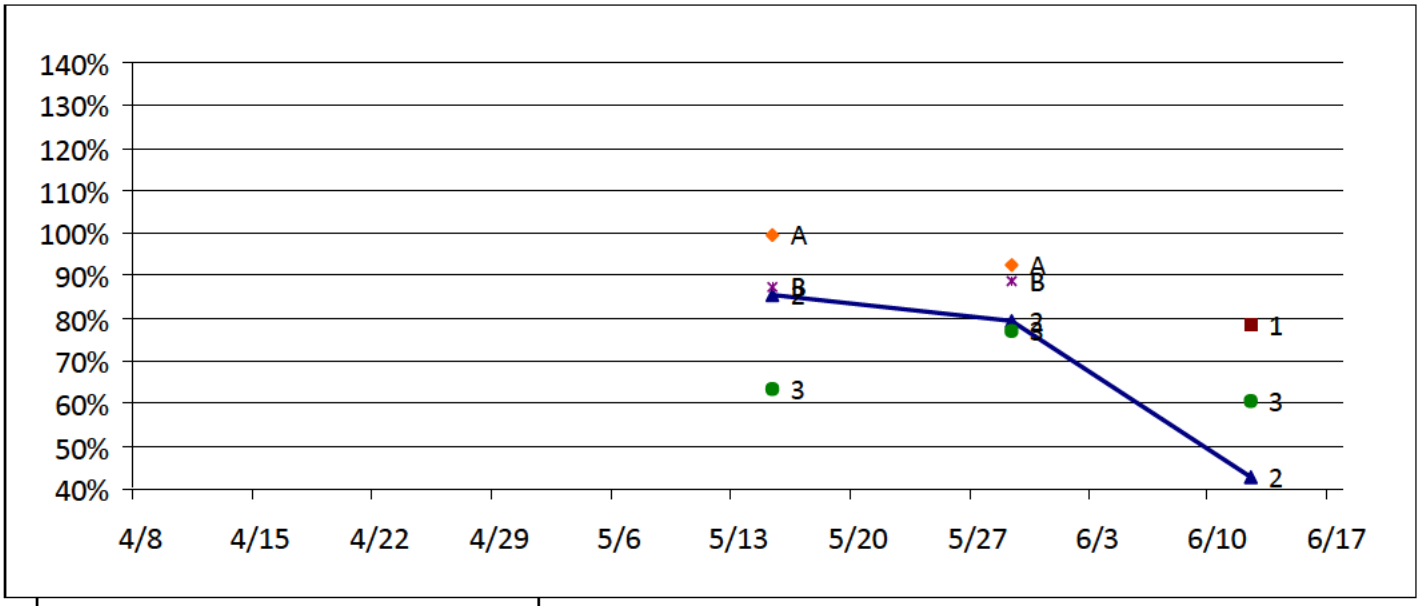
4071 I13-0652
Y

Grower Name
Grower Address

Sample Date: 6/12/2013
Sampler: Ollard
Field Bio: SS: North of pivot

Irrigation Outside Sample Strip Sampled Inside Sample Strip

Comments: System ON NE of pivot - sampled on a hill NW of pivot. Canopy at 70%; height is 24-30". Recently dammer-diked. No weeds present.



Sample Strip

Depth	% AW
1'	79%
2'	43%
3'	61%

Sample Strip
2.74 in. depletion in ASD
1.18 in. depletion in ERD

Avg Sampling Depth (ASD): 3.0
Effective Rooting Depth (ERD): 1.5
Projected Daily Consumptive Use (DCU): 0.20
Projected Weekly Consumptive Use: 1.4

Rain Gauge AVG: 1.50

This field is also trending downward following the recent dammer-diking. Suggest you could now plan to apply up to 1.7"/week this next week to meet plant need and some deficit and possibly a further increase the following week, if the weather is warm. Thanks, Scott.

Est. Recheck Date: 6/26/2013

Reviewed By: Scott Stephen
(509) 949-8843